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RESEARCH MEMORANDUM

TIME HISTORIES OF MANEUVERS PERFORMED WITH AN F-86A AIRPLANE DURING SQUADRON OPERATIONS

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TIME HISTORIES OF MANEUVERS PERFORMED WITH AN F-86A AIRPLANE DURING SQUADRON OPERATIONS

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SUMMARY

Some preliminary results of maneuvers performed during U. S. Air Force squadron operations with an F-86A jet-fighter airplane are presented in time-history form. The maneuvers cover a speed range from the stall to 530-mile-per-hour indicated airspeed and pressure altitudes varying from sea level to approximately 25,000 feet. Variation of the maximum airplane linear and angular accelerations experienced during the investigation are also presented.

INTRODUCTION

The use of rational methods for determining the design loads on tail surfaces requires, among other things, a knowledge of the control motion. At present, the control motions and consequent airplane motions used in these rational methods are purposely specified so as to produce maximum loads. Although the motions used are adjusted to be within the pilot's strength and the control range, questions have arisen as to whether such severe motions are necessary because their use results in an increase in structural weight.

Since very little is known concerning the rates, the amounts, and combinations of control motions used by pilots in carrying out regular missions, a program has been started to obtain such information. For the present, the program is aimed at obtaining sample measurements on several fighter airplanes. For each airplane used in the program it is planned to record 200 to 250 maneuvers during routine squadron operations. These maneuvers are to be divided among four or five pilots in order to obtain some cross section of pilot effect. The U. S. Air Force and Bureau of Aeronautics are cooperating with the NACA in this program; the Services furnish the airplanes and pilots while the NACA installs and maintains the instruments as well as evaluates the records obtained.

The present paper includes measurements obtained during October and November 1950 on an F-86A airplane attached to the 335th Fighter Squadron while stationed at Andrews Field, Md. The maneuvers were recorded during regularly scheduled squadron missions. Unfortunately, these tests were interrupted when less than half way completed due to damage sustained by the airplane in landing, so that the sampling was not so extensive as was desired. The data obtained thus far are made available, with only a minor analysis, while the tests continue with another F-86A.

AIRPLANE

The airplane used in these tests was a standard Air Force F-86A. The F-86A is a single-place, swept low-wing fighter and is powered by a single General Electric J-47 series axial-flow turbojet engine. The airplane has automatic full-span leading-edge slats, partial-span slotted flaps, and fuselage speed brakes. The longitudinal control system includes an adjustable stabilizer (used for control at high Mach numbers as well as for control force trim) and a hydraulically boosted elevator.

During the tests neither the external appearance nor the weight and balance of the airplane was altered by the inclusion of the recording instruments. A three-view drawing of the airplane is given in figure 1 and its over-all characteristics are included in table I.

INSTRUMENTS

Standard NACA photographically recording instruments were used to measure (1) the quantities defining the flight conditions which are airspeed, altitude, slat position, and speed brake position; (2) the pilot-imposed control motions; and (3) the response of the airplane in terms of angular velocities and linear accelerations. The recorders were synchronized at $\frac{1}{2}$-second intervals by means of a common timing circuit. In order to relieve the pilot of any instrument switching procedure and hence assist in obtaining normal operations, a specially designed pressure switch was incorporated to turn on automatically the instruments at 90 miles per hour. All recorders were mounted in the nose section with the exception of the three-component accelerometer which was in a fuselage access compartment above the wing.

A standard two-cell pressure recorder connected to the airplane service system was used to measure the altitude and airspeed. The service system employs a total-pressure tube located in the nose inlet and flush static-pressure orifices on either side of the lower fuselage forward of the wing root. (See fig. 1.)

Microswitches were incorporated on the right wing slat and on the speed brake cockpit control handle to indicate time of opening of these surfaces. The control positions were measured by remote recording electrical transmitters installed at the control surfaces.

The elevator, rudder, and stabilizer transmitters were installed inside the tail fairing to take measurements at the inner hinge. Aileron deflections were obtained with a transmitter located at approximately the aileron midspan.

Angular velocities were recorded about three mutually perpendicular axes in which the longitudinal reference axis is the one commonly used for leveling the airplane. (See fig. 1.) Linear accelerations along these three axes were recorded by a three-component accelerometer located in the fuselage 3.1 feet forward, 1.3 feet above, and 1.8 feet to the left of the measured center of gravity with full fuel. (See table I.)

Table II is a summary list of the quantities measured, the instruments used, the accuracy of the measurements, and the instrument natural frequencies. The accuracy of the measurements was estimated with regard to errors resulting from instrument characteristics and reading limitations. All recording instruments were adjusted to about 0.65 of critical damping. The natural frequencies of the elements in the three-component accelerometer were selected to give the best compromise value which would minimize the magnitudes of extraneous vibratory accelerations and still give correct response to the maneuver.

TESTS

The recorded measurements were obtained in routine squadron operations. Other than to request that the airplane be used in as many types of missions as were normally carried out by the squadron, no attempt was made to specify or influence the maneuvers. Since the pilots were aware of the instrumentation it was stressed that this not restrict their normal handling of the airplane as they would be unidentified with the test results. Sufficient film was available during each flight to obtain 40 minutes of continuous records. Because of the automatic airspeed switch this amount of time was generally sufficient to cover the entire flight.

During the course of the tests, eight flights were made of which five were used. The flights were made without external fuel tanks or stores. A total of three pilots participated and in all cases were equipped with g-suits. Table III is a summary of the scope of the tests and lists for each flight, the pilot, scheduled mission, airplane weight and center-of-gravity position, configuration, and the number of maneuvers. The listed values for the weight and center-of-gravity position were estimated and apply at the time of actual take-off and do not include the fuel used for starting, warm-up, and taxying. In evaluating the data an interpolation was made to determine the weight and center-of-gravity position existing at the time of each maneuver.

With regard to the number of maneuvers it is to be noted that during a flight it was usual to record long periods in which all quantities were constant. These periods would be interrupted by what has been designated in table III as a maneuver but which in reality would be a series of maneuvers in which one merged into another before a steady condition was finally reached. In some cases a maneuver would consume a period up to 80 seconds.

METHOD AND RESULTS

The basic results obtained are presented in figures 2 to 53 as time histories of the measured quantities. In these figures the altitude is the usual standard pressure altitude and the airspeed is given in terms of indicated airspeed (the reading of a differential-pressure airspeed indicator calibrated in accordance with the accepted standard adiabatic formula to indicate true airspeed for standard sea-level conditions only). No correction has been made to the recorded quantities for position error. Reference 1 contains a discussion of errors in the F-86 airspeed system.

The control-position curves shown for the aileron, elevator, and rudder were measured with respect to their stick-locked neutral positions. Only the right aileron angle was measured. The stabilizer position was measured with respect to the airplane reference line. Periods during which the right wing slat and speed brakes were open are indicated in the figures by the arrowed lines. The extent of each line does not imply that the slat was fully extended for that period since the measuring device simply indicated when the slat was displaced from the retracted position.

In the figures, the linear accelerations are given in g units and the angular velocities are in radians per second. Linear accelerations acting upward, forward, and to the left are positive in this paper. Nose-upward pitching angular velocities are positive as are rolling and yawing angular velocities to the right. No corrections have been made to the recorded linear accelerations to account for angular and centrifugal acceleration effects on the recorder which was not mounted at the center of gravity. The corrections introduced by these effects are important only for the transverse acceleration where high rolling velocities or accelerations occur.

Figure 54 shows the portion of the operational V-n diagram covered by the present maneuvers. The values for airspeed and load factor were taken directly from the time histories.

From the time-history curves of figures 2 to 53 several plots of quantities of interest in loads and stability work were obtained. The variation of maximum pitching, rolling, and yawing acceleration with indicated airspeed is given in figures 55, 56, and 57, respectively. The acceleration values shown were obtained from the slopes of the angular velocity curves. As mentioned previously, it was seldom that the pilot made a single maneuver such as would occur in research flight testing. Therefore, in general, several values for the maximum angular accelerations existing in each definite airplane motion were available from each time history. In plotting these maximum values only the points above some lower arbitrary limit were included as being significant. These limits were 0.1 radian per second per second for pitch and yaw and 0.5 radian per second per second for roll.

Data from the unaccelerated-flight portions of the records were used to obtain the variation of elevator trim position with airplane normal-force coefficient shown in figure 58. These results apply to the case with gear up and speed brakes retracted.

DISCUSSION

It is apparent from the maximum values of indicated speeds and altitudes attained in this investigation that the present sampling does not include the extreme conditions that the F-86A is capable of. (See fig. 54.) The figures do represent, however, a cross section of maneuvers performed in training. Although the data are limited to a few hours of flight time, it is to be noted that the maneuvers made include a majority of those used in the tactical use of this airplane including Immelman turns, barrel rolls, dives and pull-outs, slow rolls, stalls, dive-bombing runs, and gunnery passes. Since the pilots did not log the details of the flights, the maneuvers were classified by the commonly accepted acrobatic terms. In those cases where it was difficult to classify a maneuver or series of maneuvers, the usual terms such as rolls, turns, and pull-ups were incorporated. Most of the standard maneuvers are interpreted in reference 2.

Examination of the time histories indicates that the higher normal accelerations occurred in Immelman turns and rapid pull-outs. The highest value obtained was about 6g and is shown in figures 37 and 52. The time histories show that maximum transverse accelerations of the order of 0.3 to 0.4 g were measured at the location of the accelerometer. However, from an analysis of the angular and centrifugal acceleration corrections, the maximum values of transverse acceleration applied at the airplane center of gravity were less than 0.15 g . The highest transverse accelerations at the airplane center of gravity occurred in barrel rolls and were associated with appreciable yawing velocity.

Very little rudder movement was used in any of the unstalled maneuvers; the greatest rates and amounts of rudder motion were used in making the half rolls during Immelman turns as for example in figure 40. This may be due to the fact that the rudder must be used not only to hold the nose up, but also to overcome the adverse yaw. As contrasted with the unstalled case the low-speed stalled maneuvers shown in figures 9 to 11 are characterized by almost full control movements and in particular by the fact that the rudder was given almost full throw each time. The greatest rates and amounts of aileron movement were used in barrel rolls. This maneuver was characterized by a pull-up to two or three g's followed by a rapid aileron throw the magnitude of which depended on the airspeed at which the maneuver was begun. In general, the aileron angle used decreased with an increase in airspeed. Large rates of aileron movement were used in making the eight-point roll as shown in figure 3.

The largest rates and amounts of elevator movement were used in Immelman turns and rapid pull-outs. Higher negative rates of elevator movement were obtained than positive rates as for example in figures 41 and 51. In the present tests, it was found that the pilots always set the stabilizer angle at less than 1° shortly after take-off and seldom changed it at any time during the flight. In this connection, the pilots never used the stabilizer for maneuvering.

In figure 55 it is interesting to note that the largest value of pitching acceleration obtained in this investigation was -1.55 radians per second per second which occurred at an indicated airspeed of 305 miles per hour during a rapid recovery from the pull-up illustrated in figure 41. This value is over twice that recorded for the highest positive value but somewhat less than the value of 3.0 radians per second per second for an airplane of the same class, obtained from the envelope of maximum pitching accelerations given in reference 3.

The scatter in the elevator trim points shown in figure 58 is the result of variables such as slat position and center-of-gravity location which could not be easily isolated. It is to be noted that the slat position was not actually measured and that the center-of-gravity variation was quite small. The Mach number effect, probably the major factor in this case, could not be taken into account because of limited data.

For the Mach number range covered, the average value of $dC_N/d\delta_e$ obtained from the figure is 0.08 and is in good agreement with the value which would be obtained from the wind-tunnel data given in reference 4.

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REFERENCES

1. Thompson, Jim Rogers, Bray, Richard S., and Cooper, George E.: Flight Calibration of Four Airspeed Systems on a Swept-Wing Airplane at Mach Numbers up to 1.04 by the NACA Radar-Phototheodolite Method. NACA RM A50H24, 1950.

2. National Advisory Committee for Aeronautics: Nomenclature For Aeronautics. NACA Rep. 474, 1933.

3. Matheny, Cloyce E.: Maximum Pitching Angular Accelerations of Airplanes Measured in Flight. NACA TN 2103, 1950.

4. Morrill, Charles P., Jr., and Boddy, Lee E.: High-Speed Stability and Control Characteristics of a Fighter Airplane Model with a Swept-Back Wing and Tail. NACA RM A7K28, 1948.

TABLE I

DIMENSIONS AND CHARACTERISTICS OF F-86A AIRPLANE

Wing:	
Total area (including flaps, slats, and 49.92 sq ft covered by fuselage), sq ft	287.90
Span, ft	37.12
Aspect ratio	4.785
Taper ratio	0.513
Mean aerodynamic chord (wing station 98.71 measured normal to center line), in.	97.03
Sweepback of 0.25 chord line, deg	35.23
Incidence of root chord (wing station 0), deg	1.0
Incidence of tip chord (wing station 220.8), deg	-1.0
Dihedral, deg	3.0
Root airfoil section (normal to 0.25 chord line)	NACA 0012-64 (Modified)
Tip airfoil section (normal to 0.25 chord line)	NACA 0011-64 (Modified)
Aileron area (each), sq ft	18.6
Aileron static control limits, deg	±14
Distance from reference datum (nose) to leading edge of mean aerodynamic chord, in.	164.26
Horizontal tail:	
Total area (including 1.20 sq ft covered by fuselage), sq ft	34.99
Span, ft	12.75
Aspect ratio	4.65
Taper ratio	0.451
Mean aerodynamic chord (horizontal-tail station 33.54 in.), in.	34.71
Sweepback of 0.25 chord line, deg	34.59
Dihedral, deg	10.0
Airfoil section (parallel to center line)	NACA 0010-64
Tail length $\left(0.25\bar{c}_w \text{ to } 0.25\bar{c}_t\right)$, in.	217.5
Elevator area (each), sq ft	5.05
Elevator static control limits (from fuselage reference line), deg	35 up, 17.5 down
Stabilizer control limits (from neutral position), deg	1.25 leading edge up, 10 leading edge down

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TABLE I

DIMENSIONS AND CHARACTERISTICS OF F-86A AIRPLANE.- Concluded

Vertical tail:	
Total area (includes 0.93 sq ft blanketed by fuselage, excludes 3.96 sq ft dorsal fin), sq ft	33.44
Span (unblanketed), ft	7.52
Height from ground, ft	14.74
Sweepback of 0.25 chord line, deg	35.0
Rudder area, sq ft	8.1
Rudder static control limits, deg	±27.5
Fuselage:	
Total length, in.	412.41
Maximum width, in.	60.0
Maximum depth, in.	60.75
Fineness ratio	6.59
Speed brake area (effective frontal area, both sides), sq ft	8.6
Power plant	GE-J-47
Measured airplane weight (full fuel), lb	13,775
Measured airplane center-of-gravity position (full fuel, gear down), percent M.A.C.	22.84
Approximate moments of inertia about reference axes through center of gravity of airplane (weight, 12,600 lb), slug ft^2:	
Pitch	16,500
Yaw	21,700
Roll	6,700

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TABLE II

ESTIMATED ACCURACY OF MEASURED QUANTITIES

Quantity measured	Unit	Instrument used	Accuracy (unit)	Instrument natural frequency (cps)
Normal acceleration	g	3-component accelerometer	±0.05	16.5
Transverse acceleration	g	3-component accelerometer	±.01	13
Longitudinal acceleration	g	3-component accelerometer	±.01	16.5
Pitching velocity	$\frac{\text{radian}}{\text{sec}}$	Angular-velocity recorder	±.02	25
Yawing velocity	$\frac{\text{radian}}{\text{sec}}$	Angular-velocity recorder	±.02	25
Rolling velocity	$\frac{\text{radian}}{\text{sec}}$	Angular-velocity recorder	±.07	25
Elevator angle	deg	Control-position recorder	±.5	14
Rudder angle	deg	Control-position recorder	±.5	14
Aileron angle	deg	Control-position recorder	±.5	14
Stabilizer angle	deg	Control-position recorder	±.2	14
Indicated airspeed	mph	Airspeed-altitude recorder	-----	High
Pressure altitude	ft	Airspeed-altitude recorder	-----	High
Time	sec	Timer	±.01	----

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TABLE III

HISTORY AND SUMMARY OF FLIGHTS

Flight number	Pilot	Mission	Configuration	Take-off weight (lb)	Take-off c.g. location (percent M.A.C.)	Number of maneuvers	Figure numbers
1	A	Acrobatic	No external fuel tanks or stores	13,500	22.9	11	2 to 12
2	B	Gunnery camera passes at tow target	-------do------	13,500	22.9	7	13 to 19
3	B	Acrobatic	-------do------	13,150	23.0	19	20 to 38
4	B	-------do------	-------do------	13,550	22.9	14	39 to 52
5	C	-------do------	-------do------	13,550	22.9	1	53

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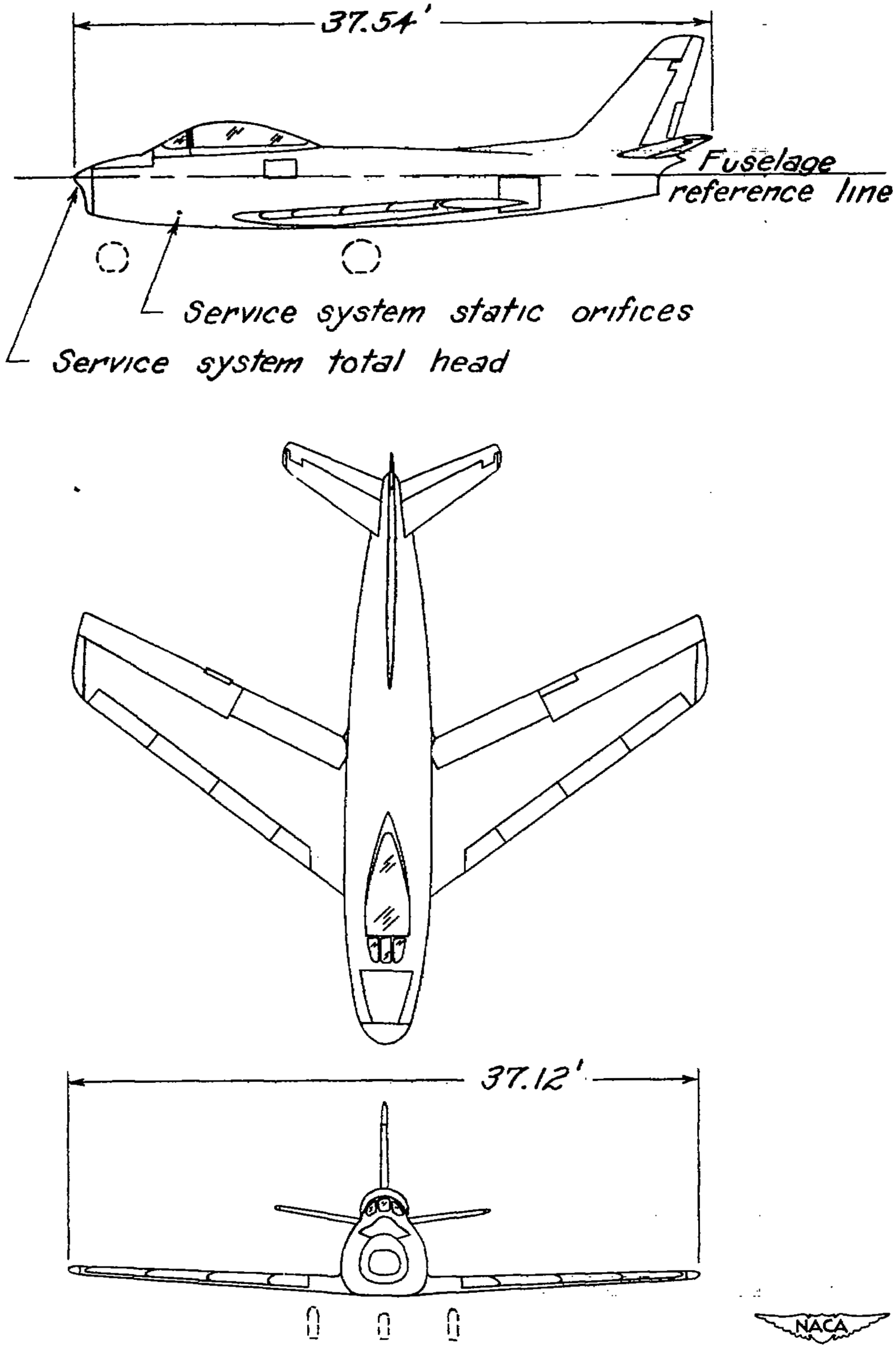

Figure 1.- Three-view drawing of test airplane.

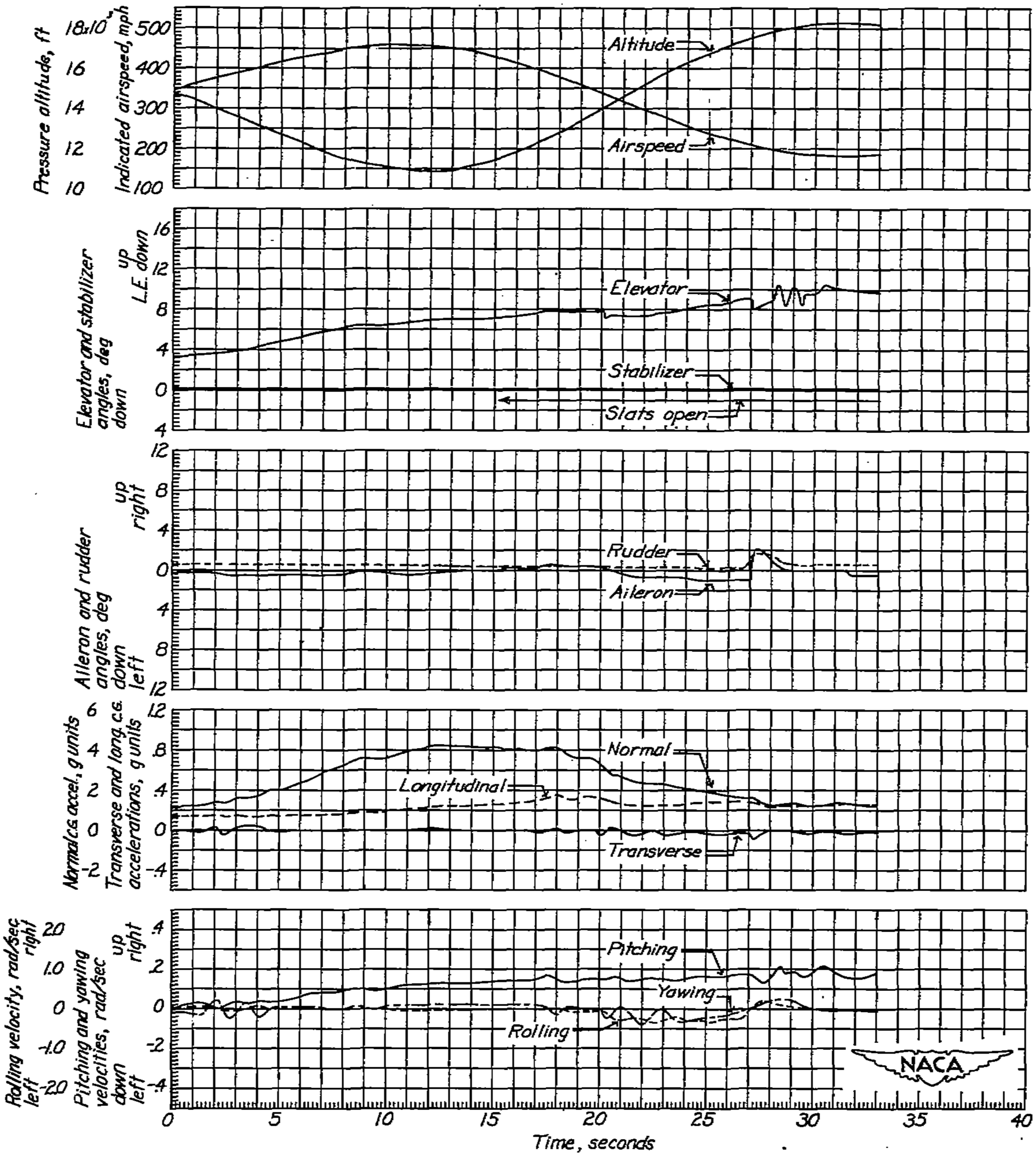

Figure 2.- Steep dive and pull-out followed by a climbing turn. Airplane weight, 13,050 pounds; center of gravity at 23.1-percent mean aerodynamic chord.

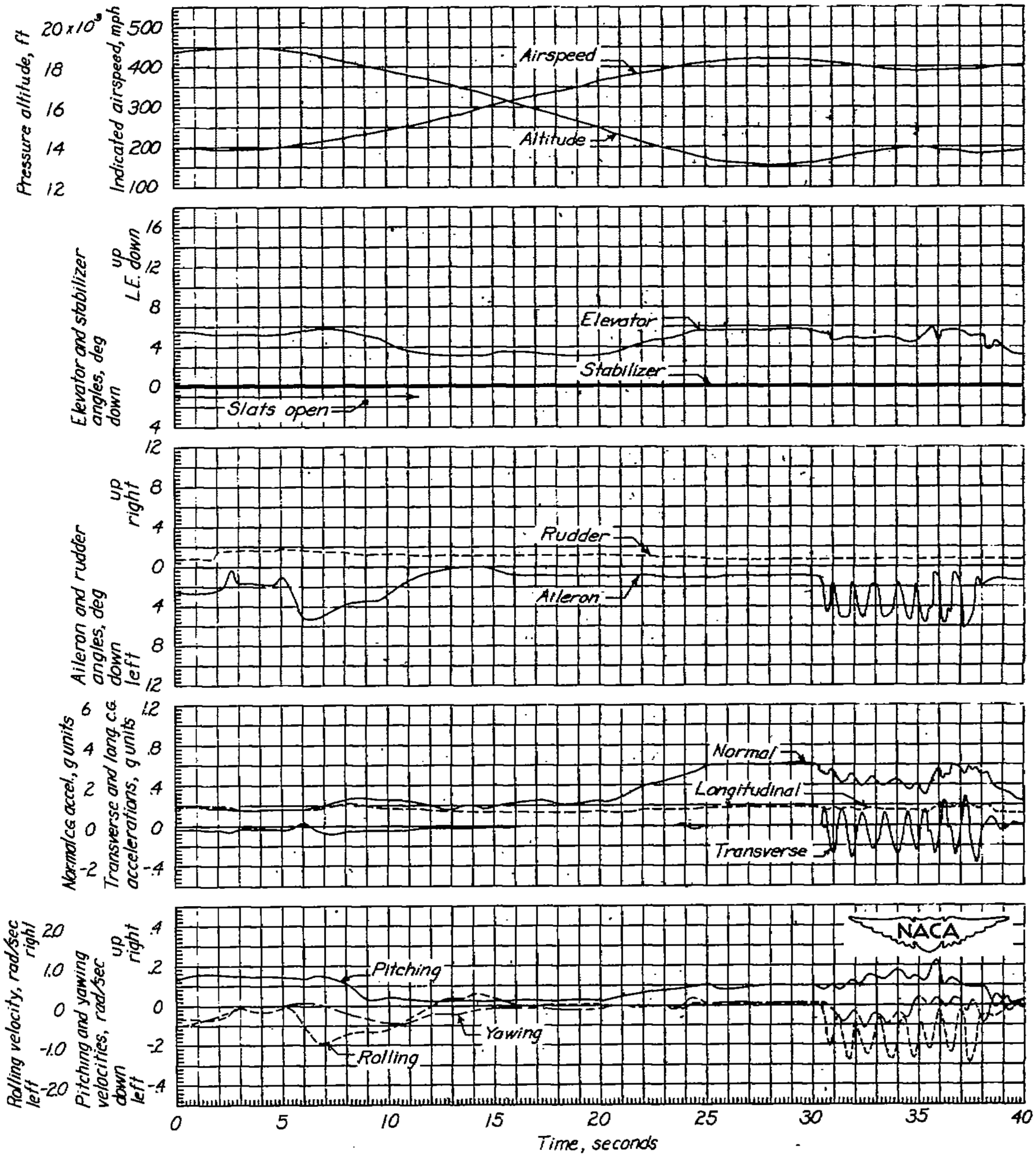

Figure 3.- Roll entry into a dive and pull-out, eight-point roll followed by barrel rolls in a climb. Airplane weight, 12,950 pounds; center of gravity at 23.1-percent mean aerodynamic chord.

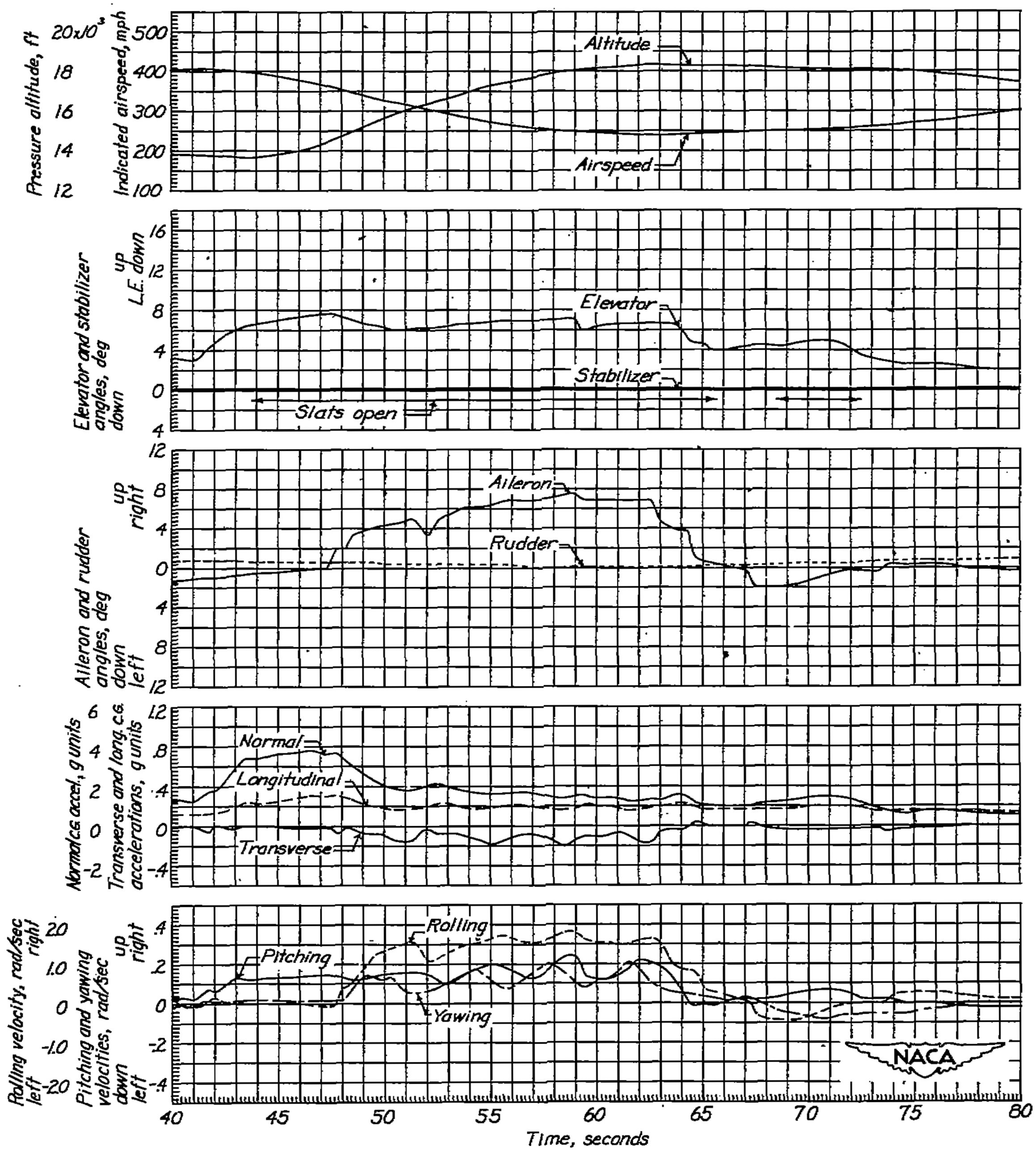

Figure 3.- Concluded.

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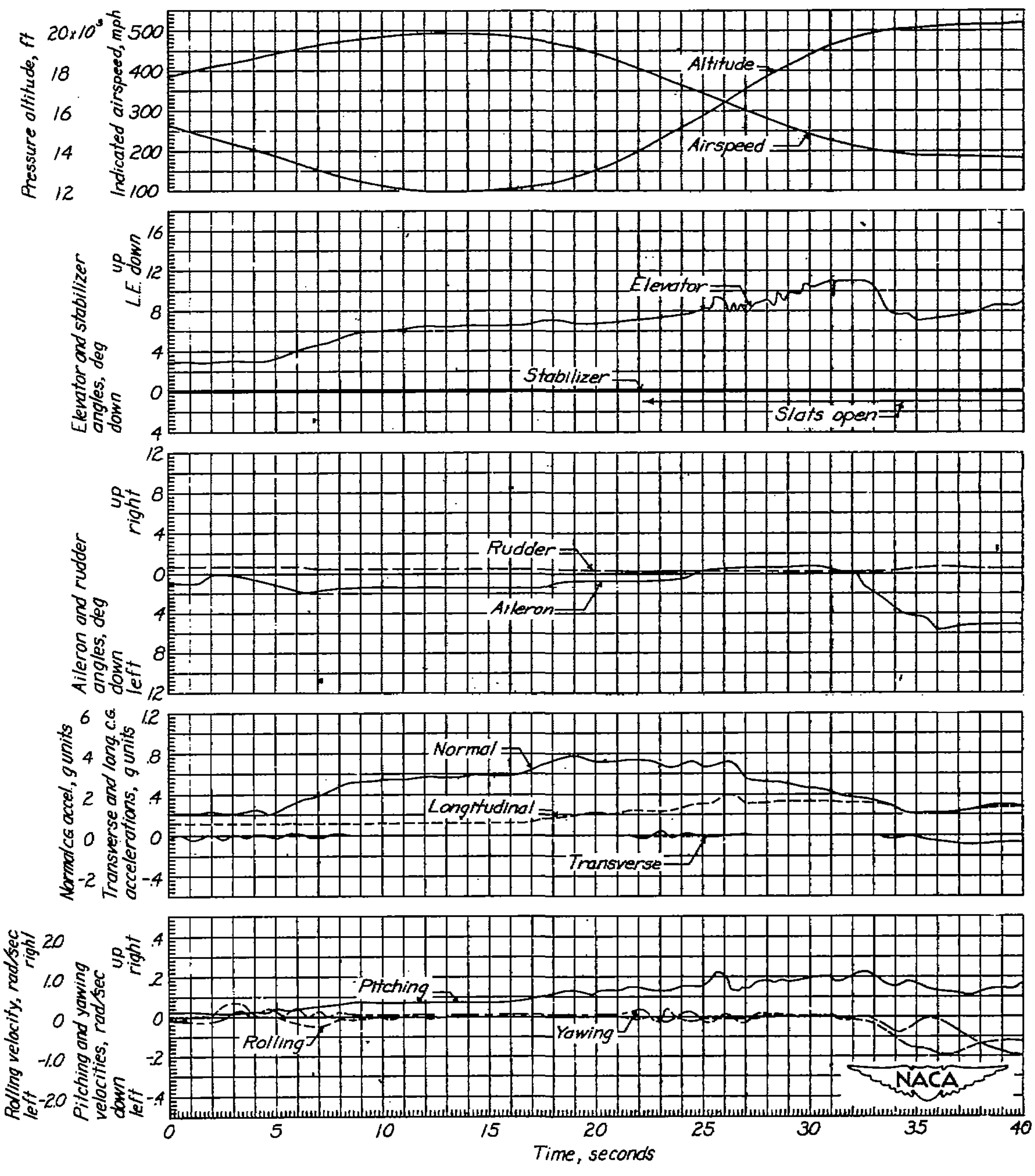

Figure 4.- Loop including 360° roll on the top. Airplane weight, 12,900 pounds; center of gravity at 23.1-percent mean aerodynamic chord.

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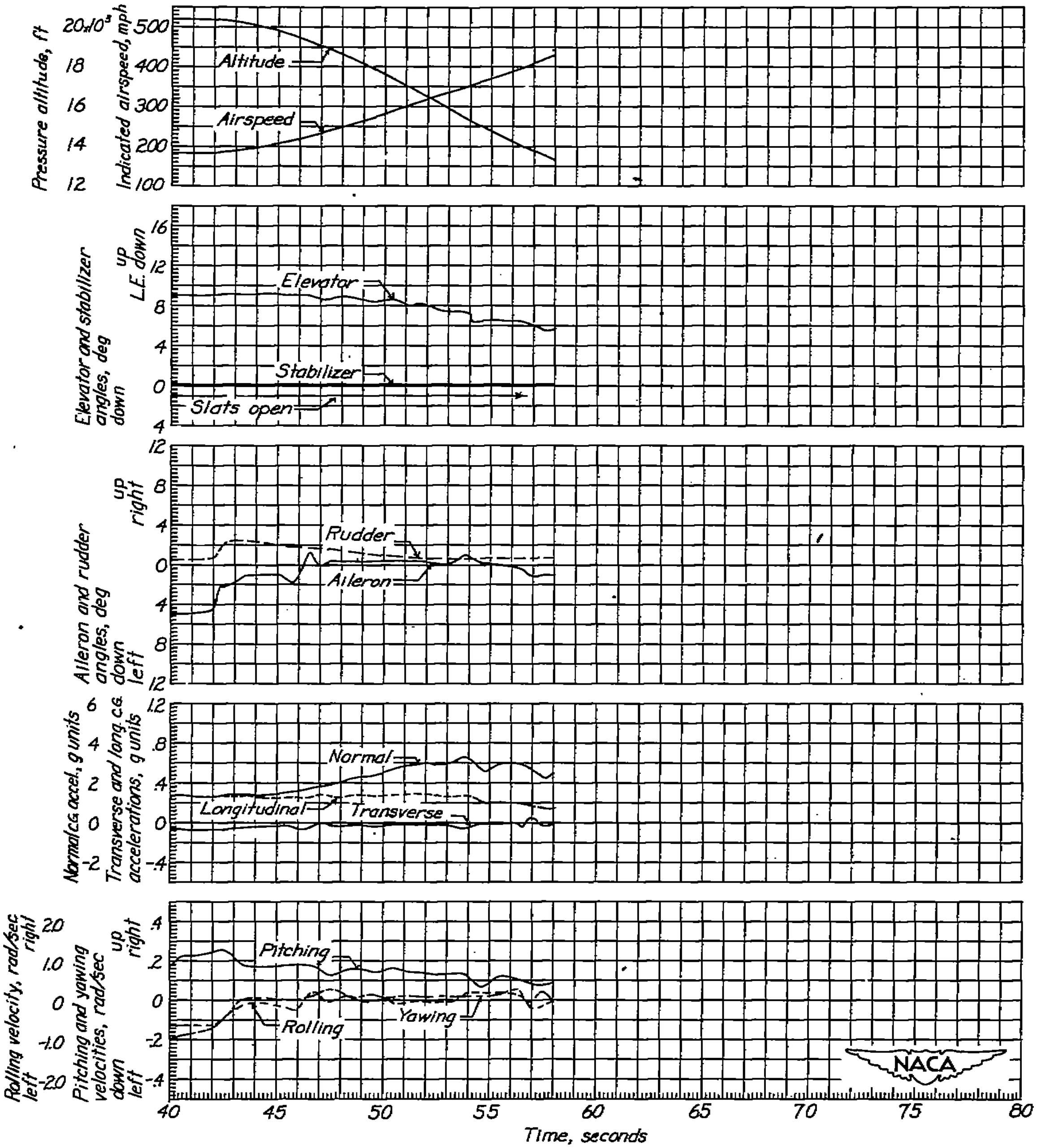

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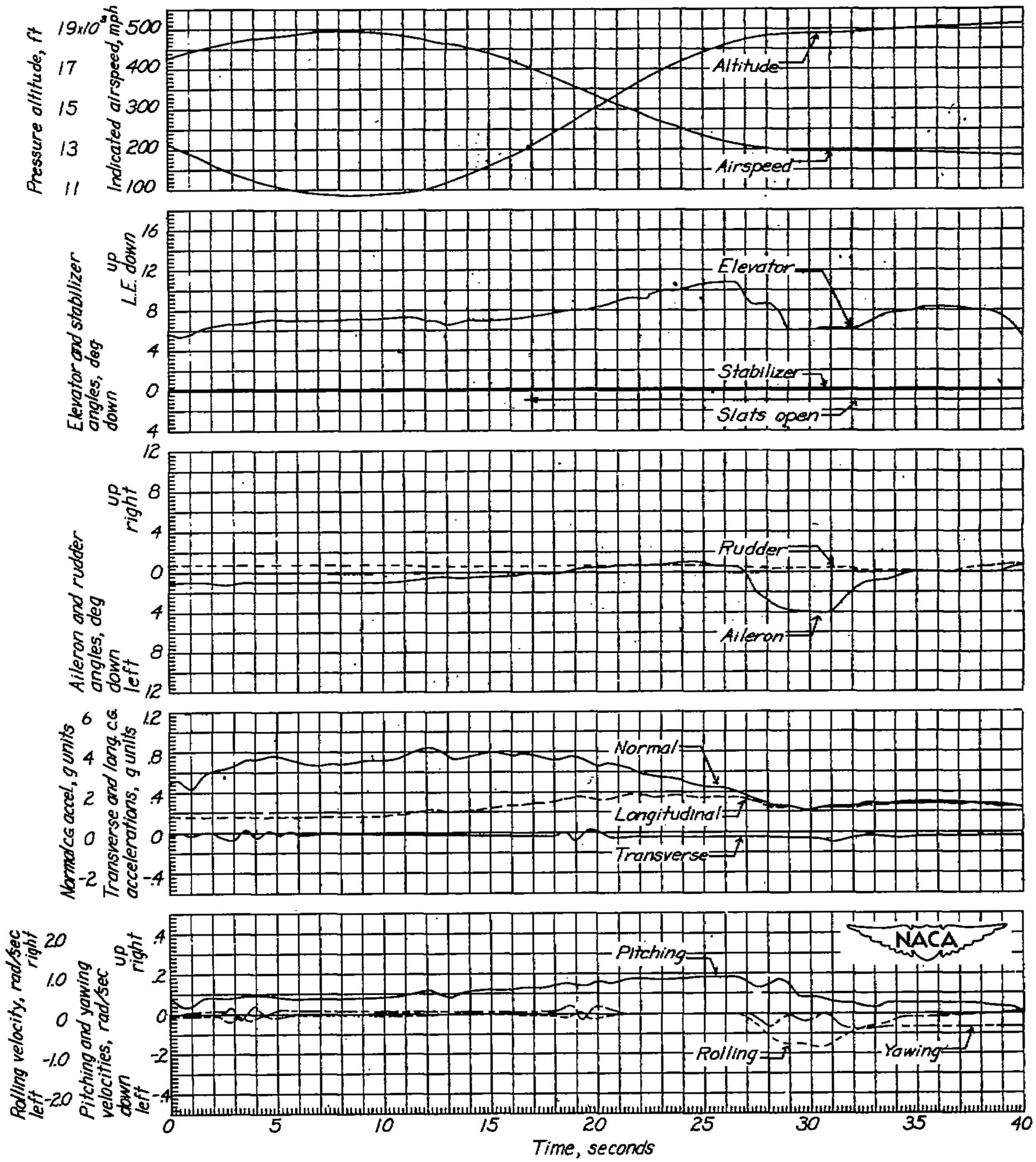

Figure 5.- Immelman turn followed by diving half-rolls and pull-out. Airplane weight, 12,850 pounds; center of gravity at 23.2-percent mean aerodynamic chord.

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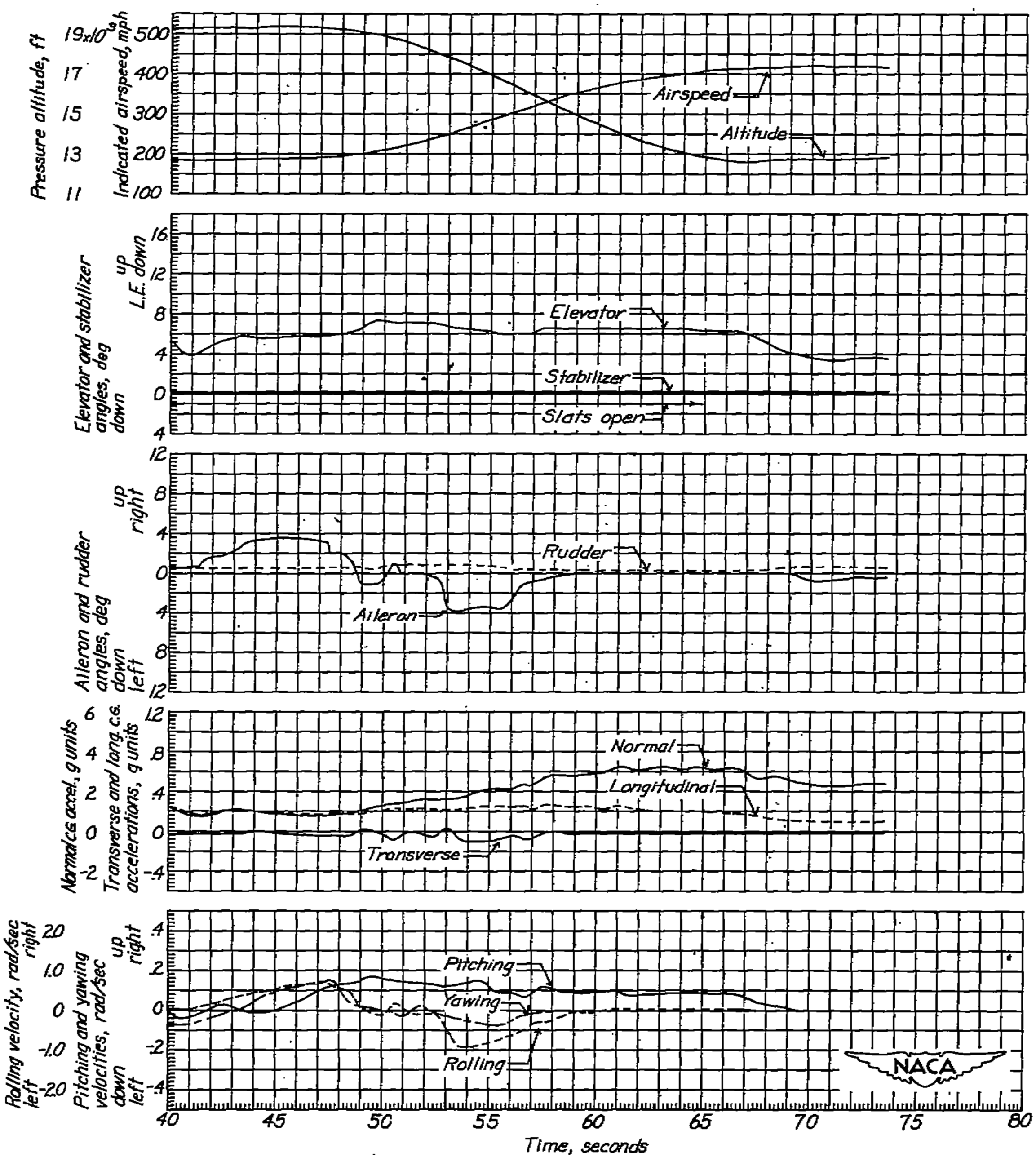

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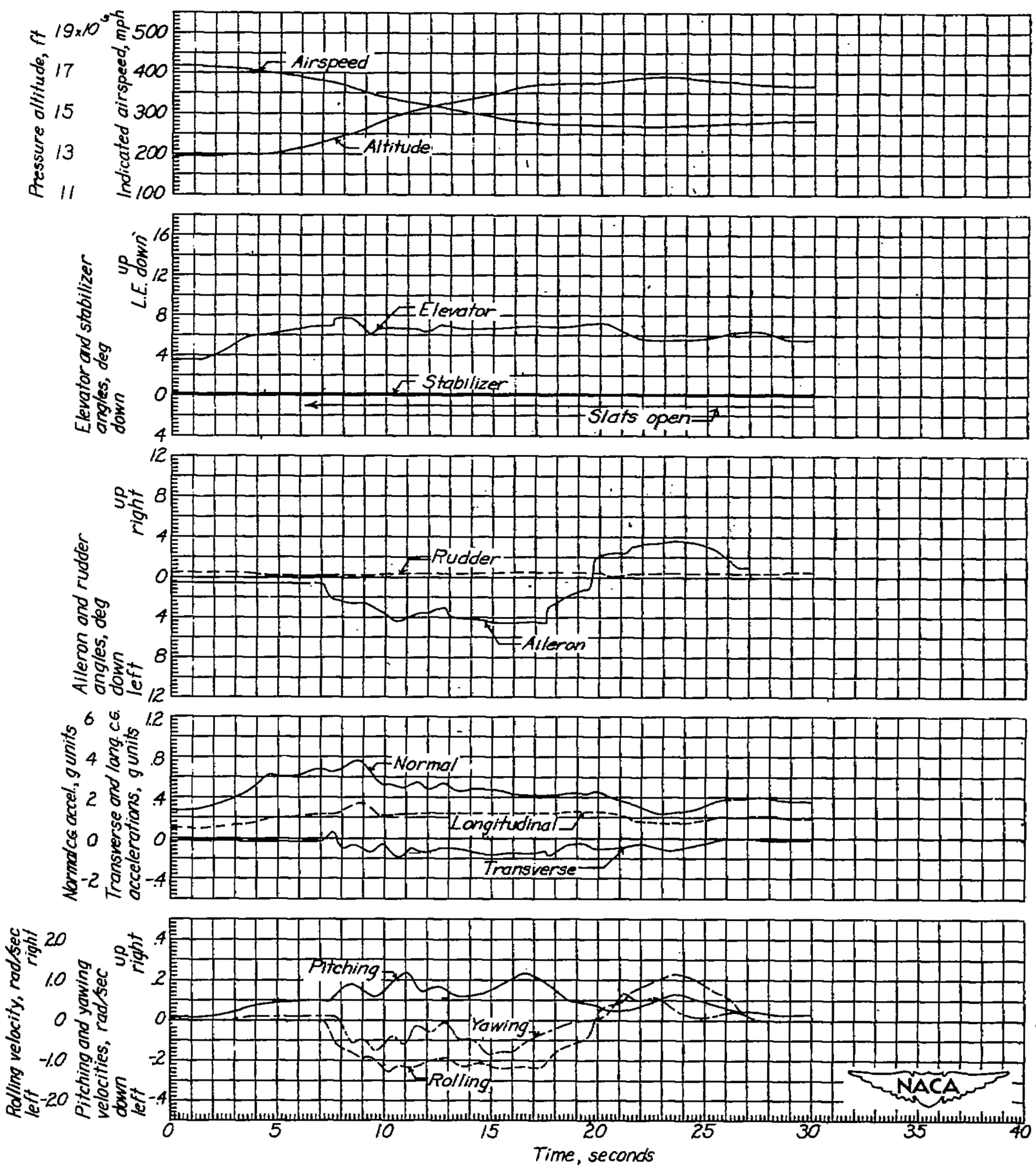

Figure 6.- Pull-up into a climb with barrel rolls. Airplane weight, 12,800 pounds; center of gravity at 23.2-percent mean aerodynamic chord.

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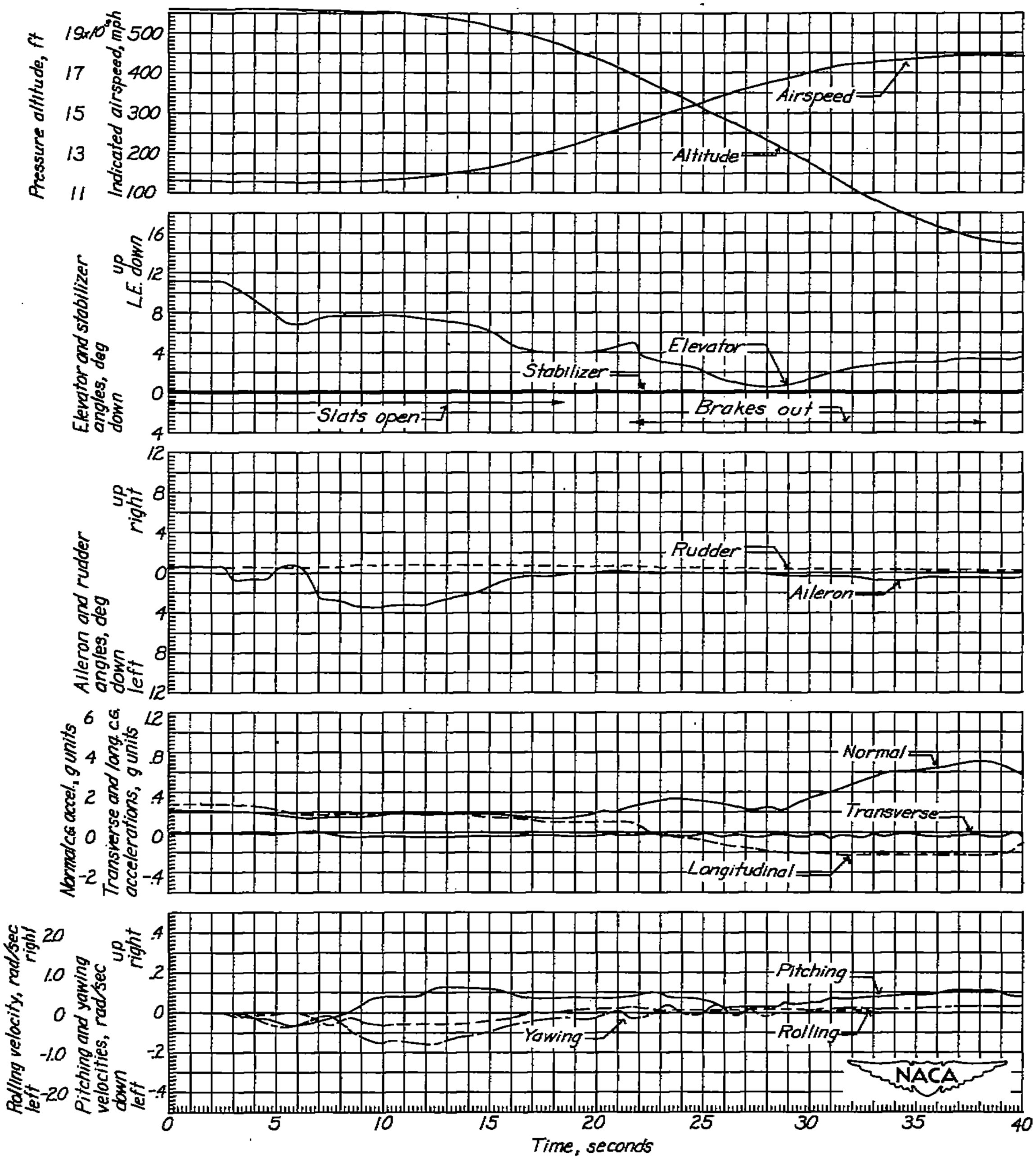

Figure 7. Turn entry into a steep dive and pull-out followed by a quarter-roll entry into an Immelman turn. Airplane weight, 12,450 pounds; center of gravity at 23.3-percent mean aerodynamic chord.

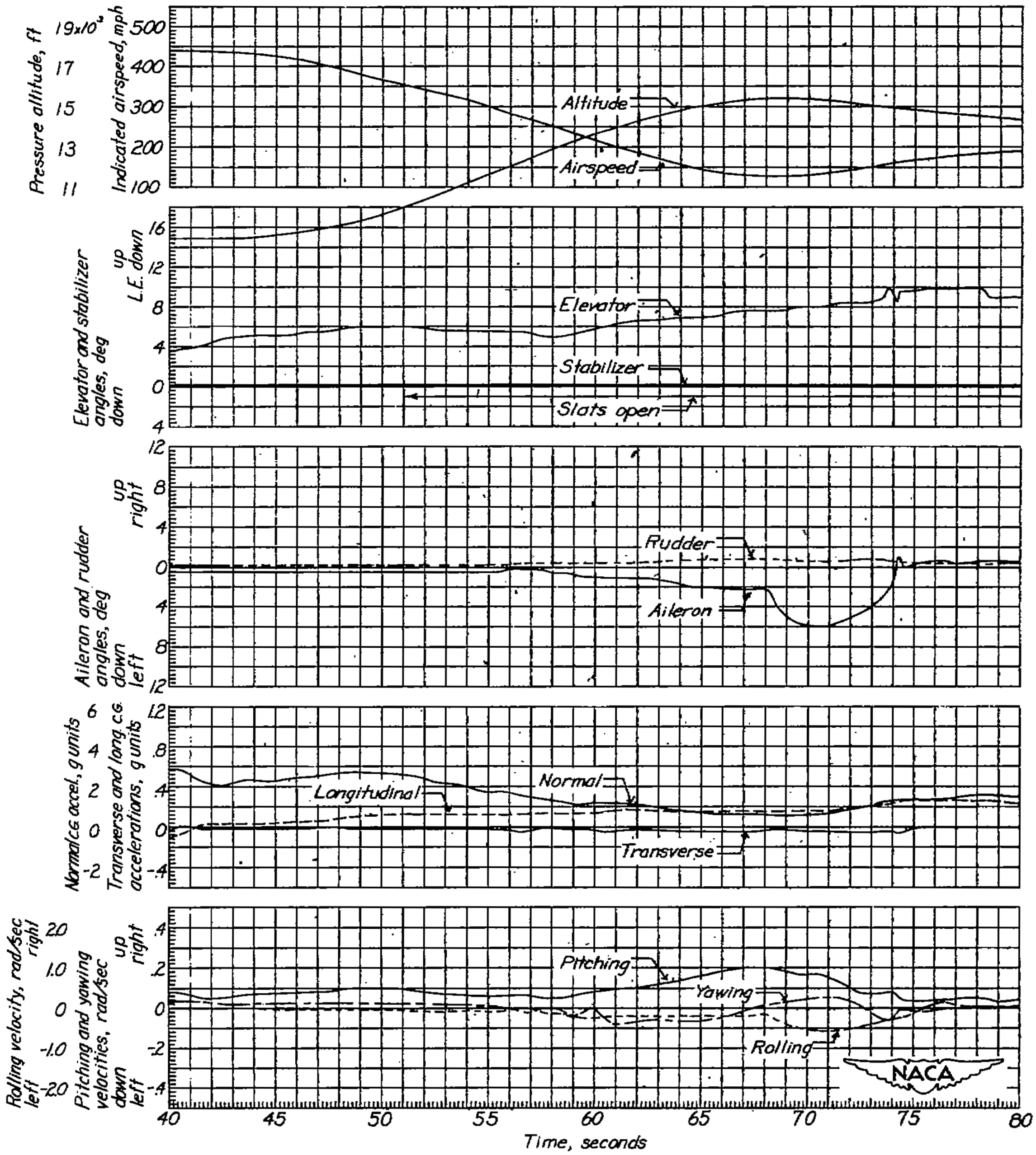

Figure 7.- Concluded.

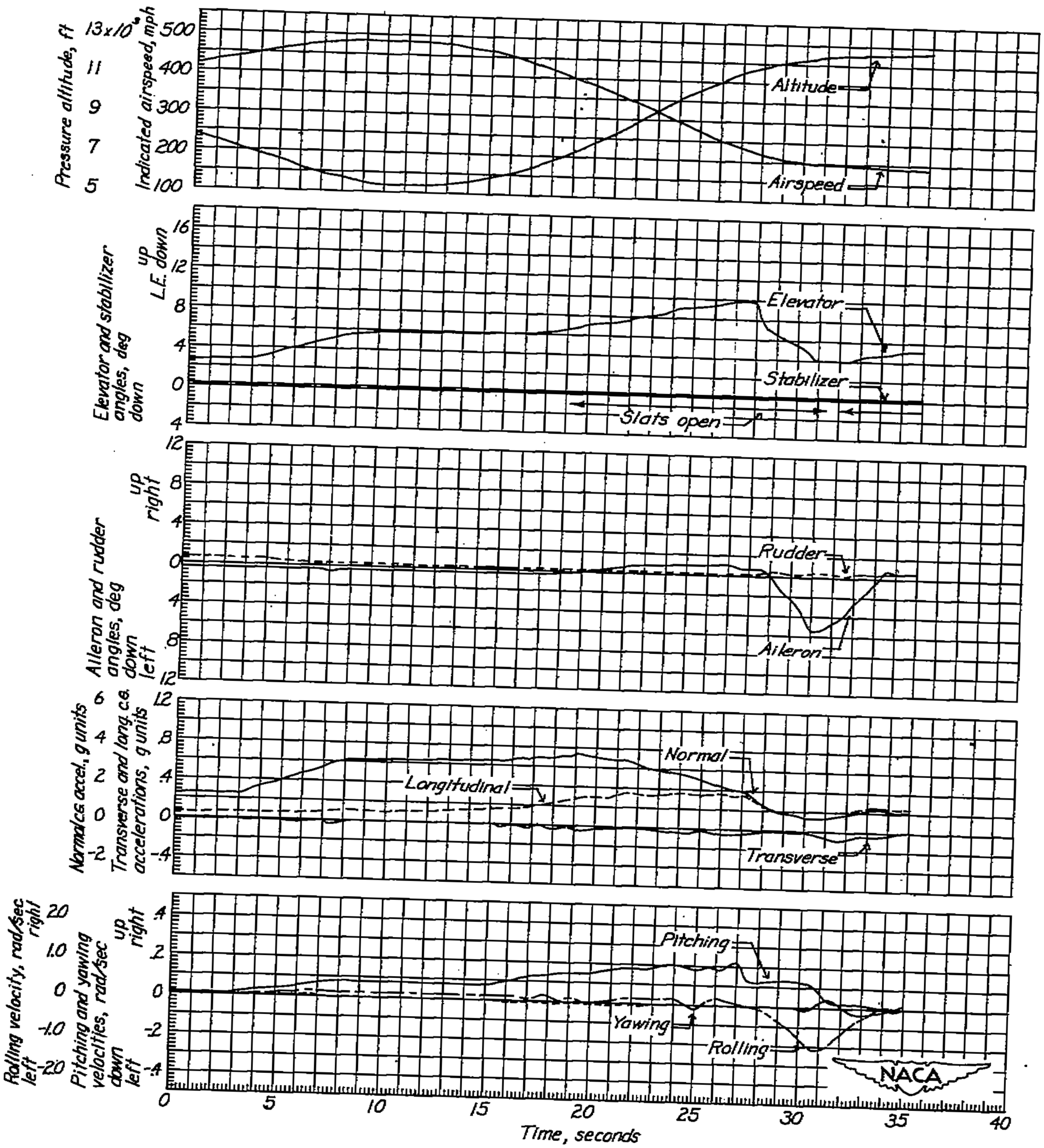

Figure 8.- Immelman turn. Airplane weight, 12,350 pounds; center of gravity at 23.4-percent mean aerodynamic chord.

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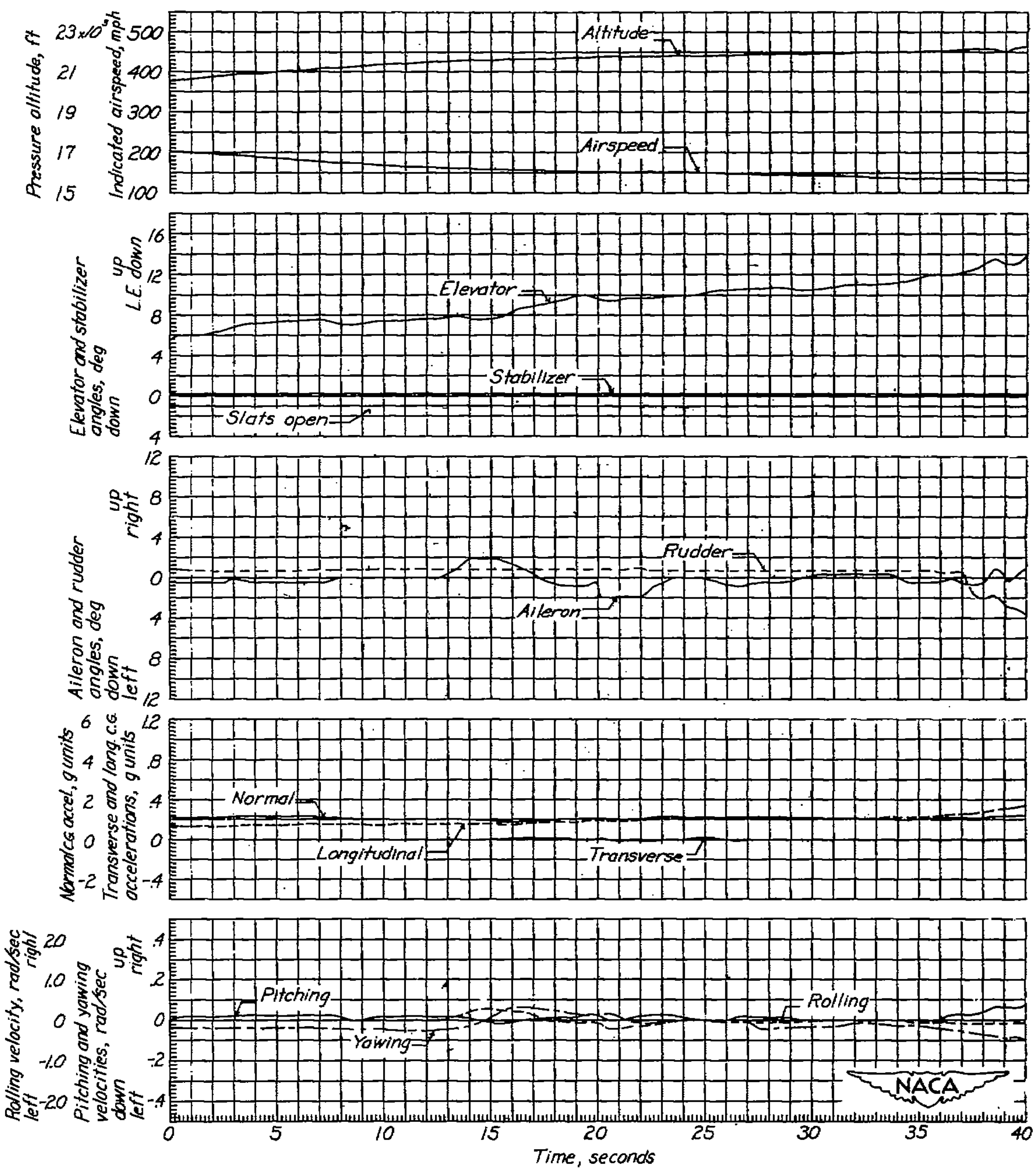
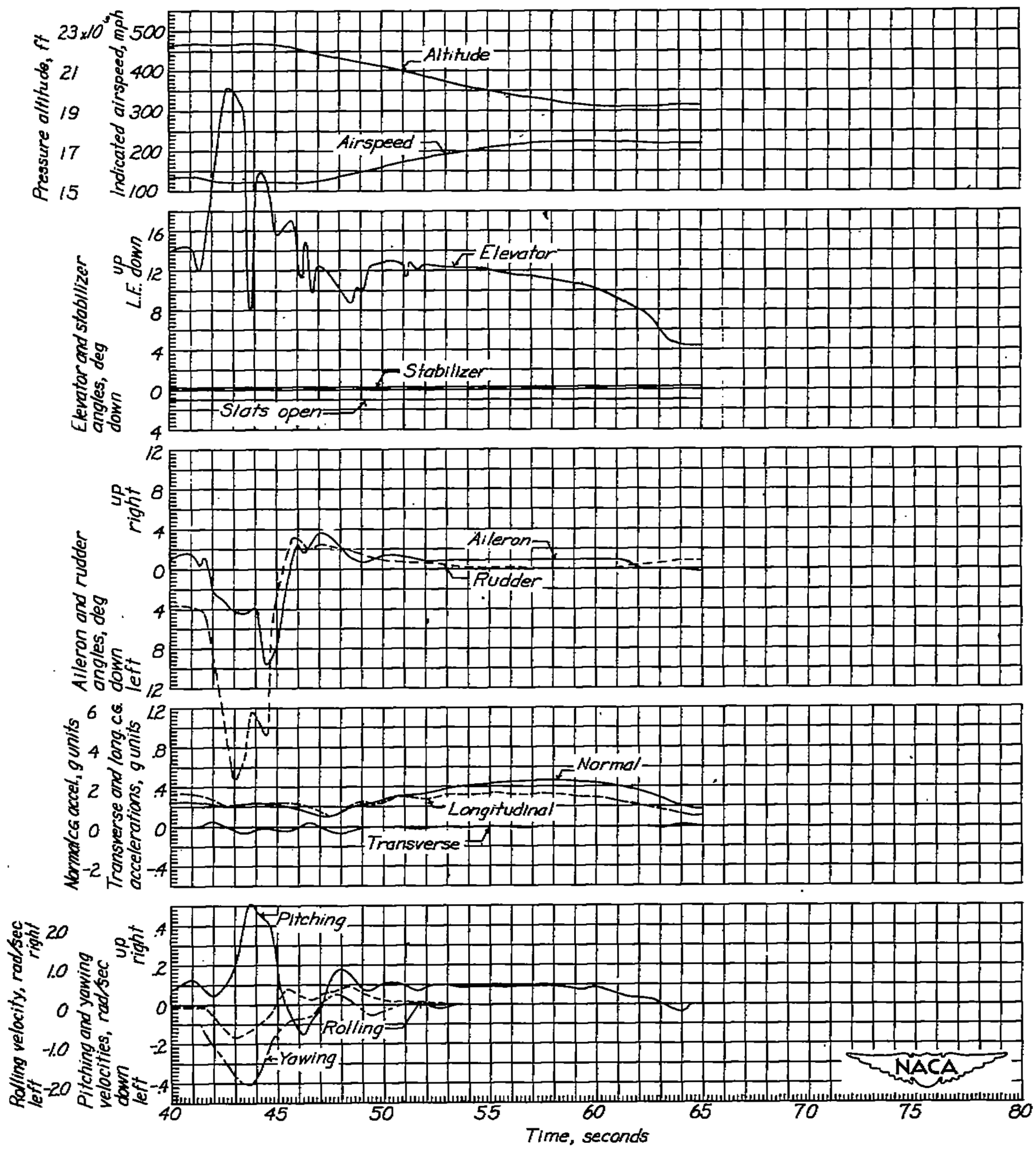


Figure 9.- Stall. Airplane weight, 12,100 pounds; center of gravity at 23.5-percent mean aerodynamic chord.



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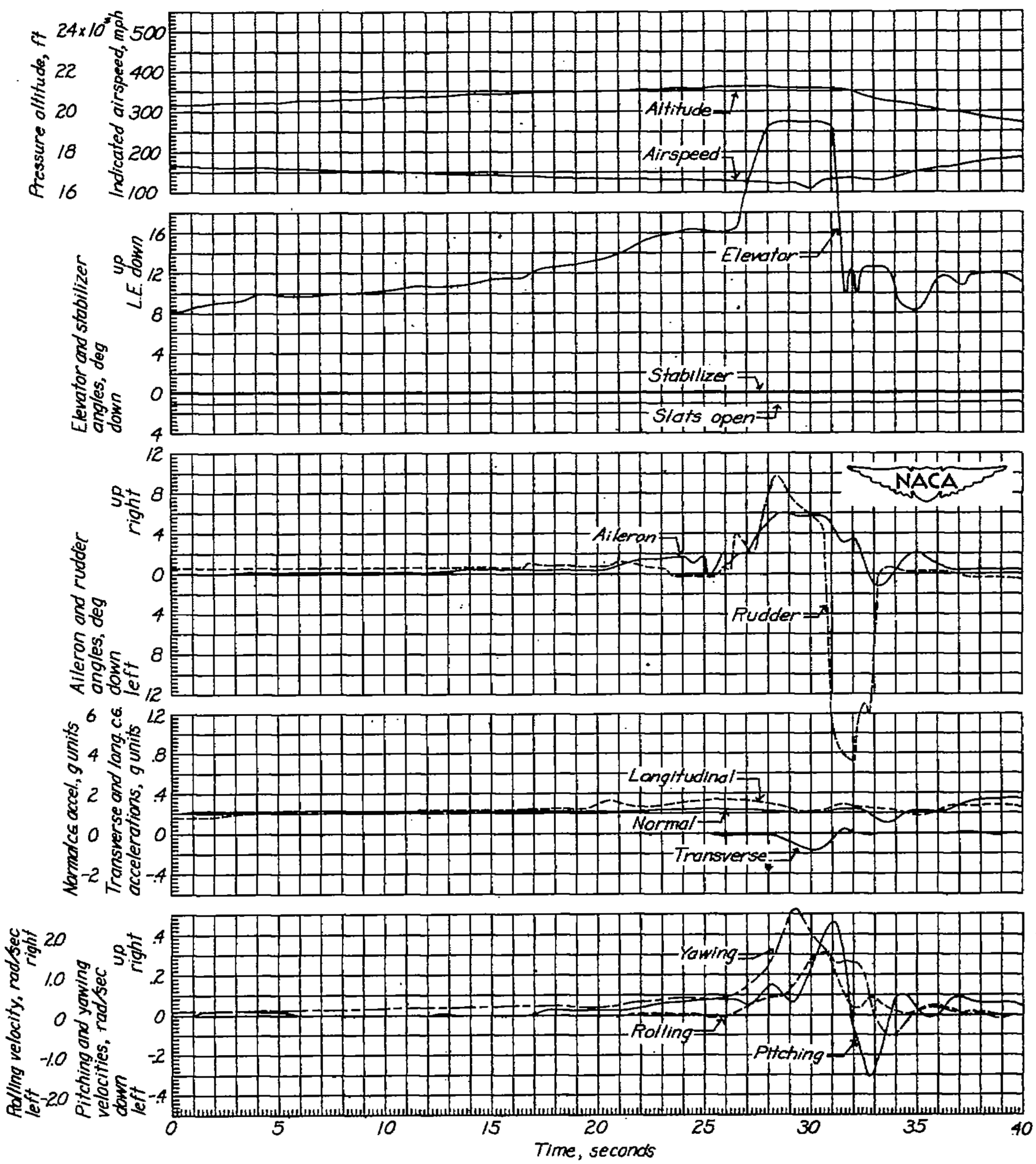

Figure 10.- Stall. Airplane weight, 12,000 pounds; center of gravity at 23.5-percent mean aerodynamic chord.

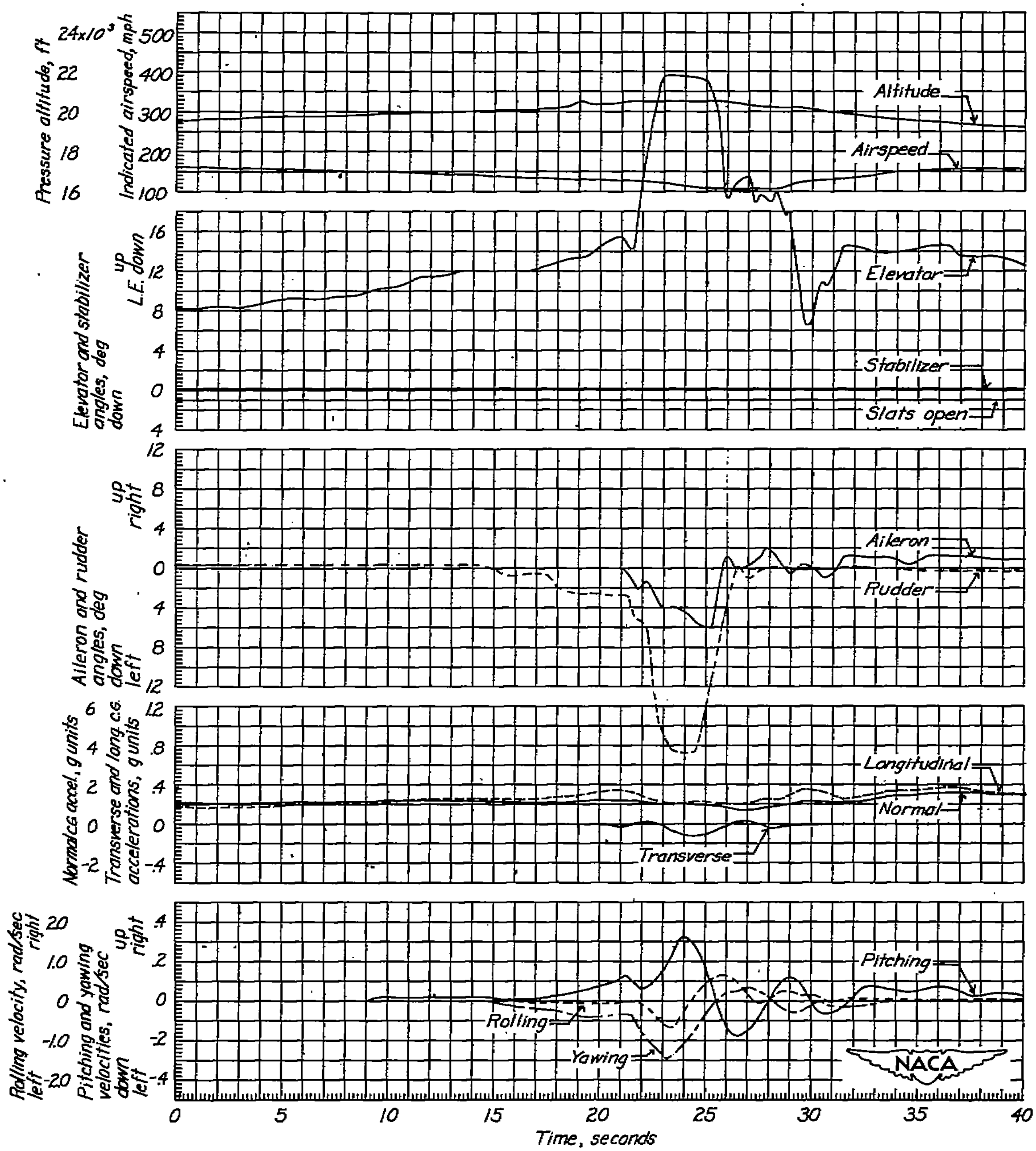

Figure 11.- Stall. Airplane weight, 11,900 pounds; center of gravity at 23.6-percent mean aerodynamic chord.

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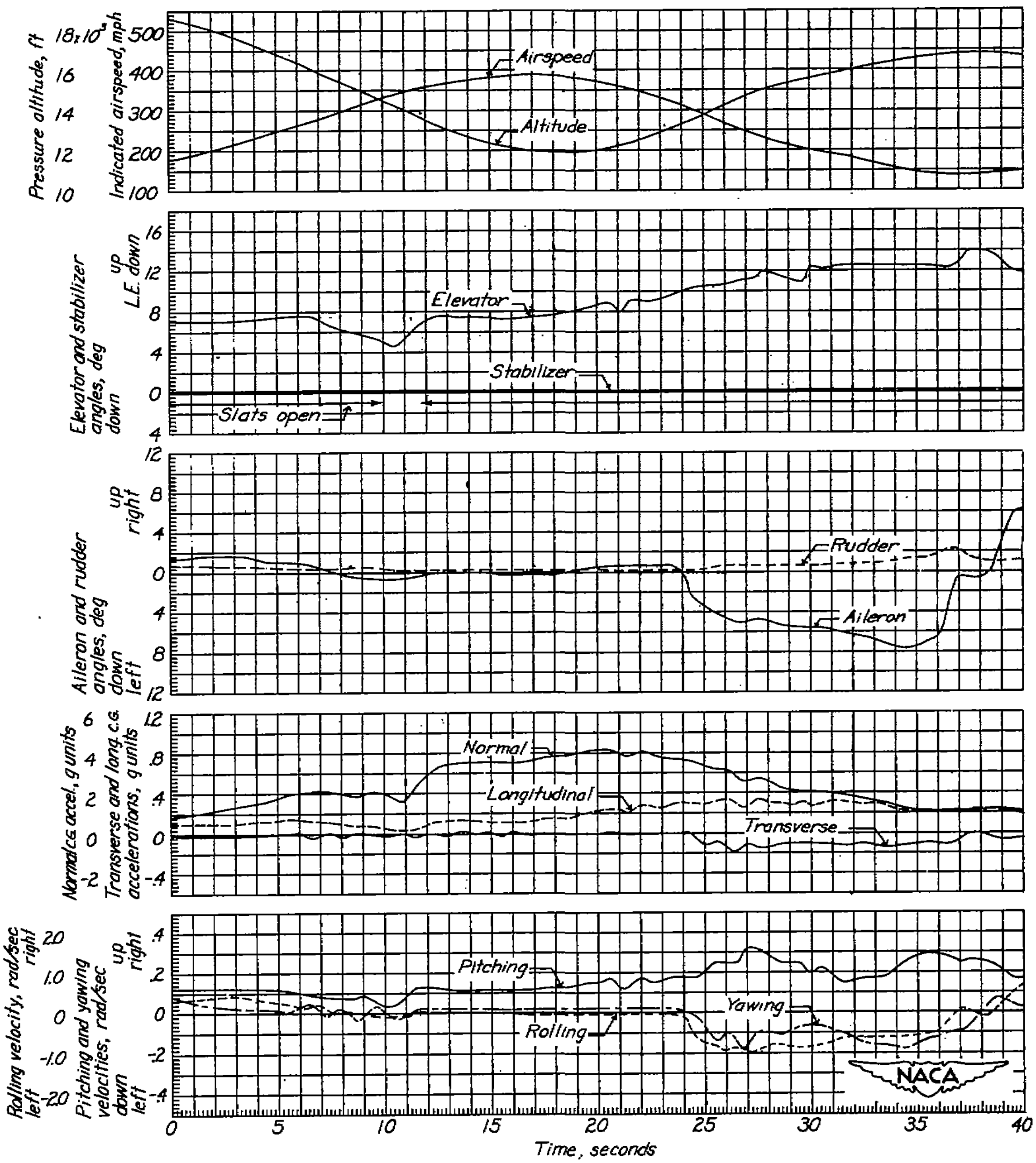
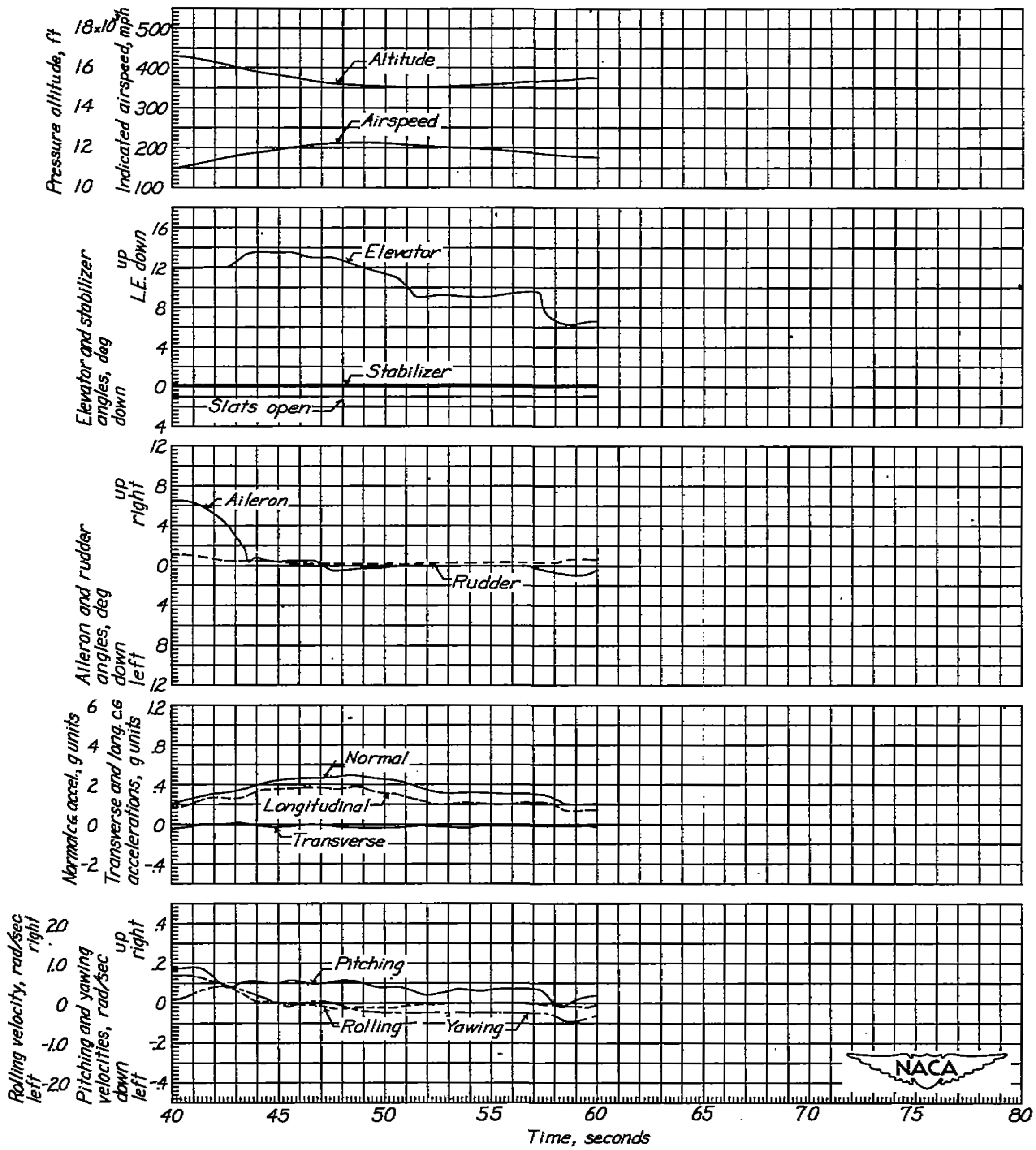


Figure 12.- Diving turn and pull-up into a climb with barrel rolls. Airplane weight, 11,850 pounds; center of gravity at 23.6-percent mean aerodynamic chord.



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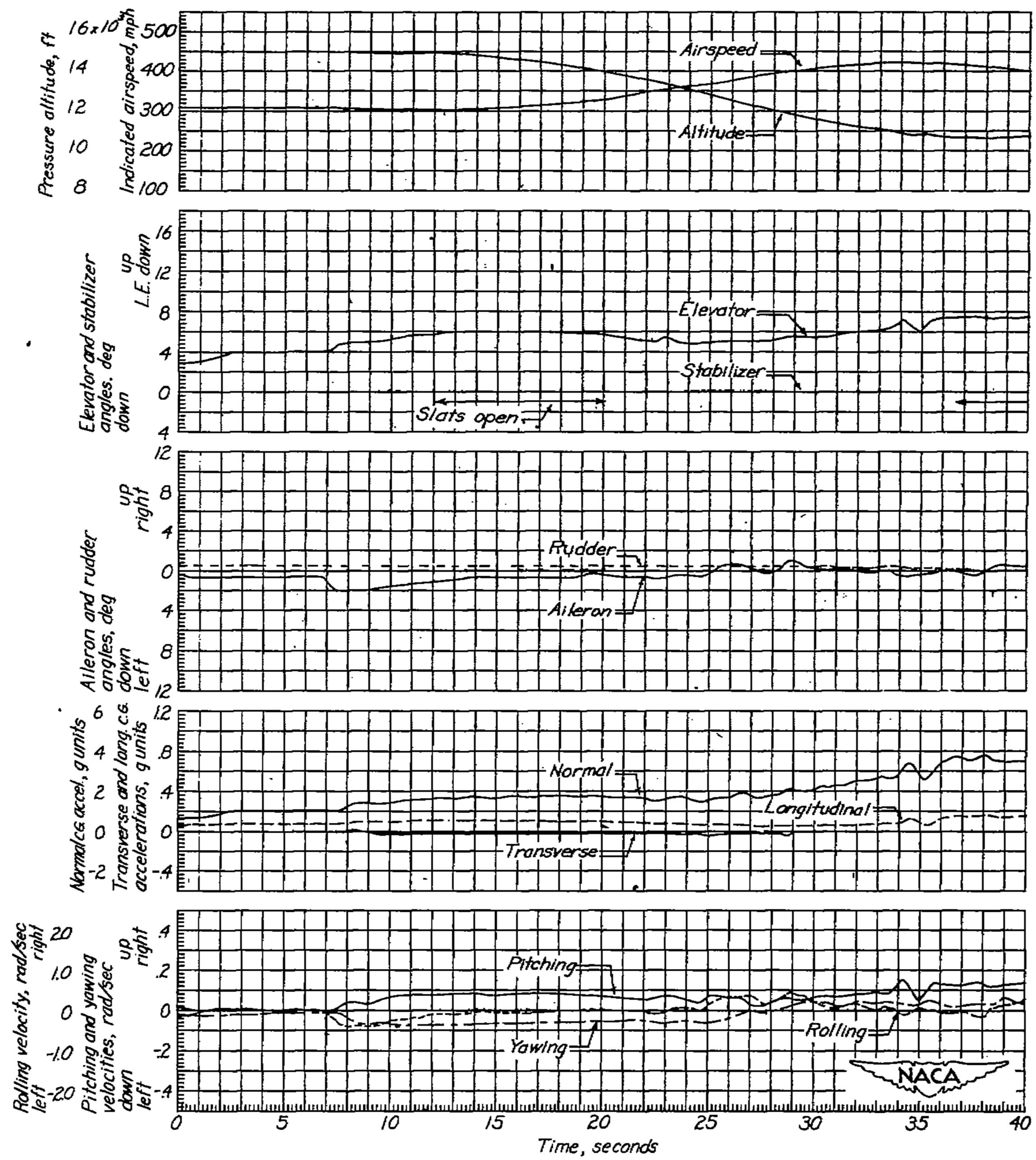
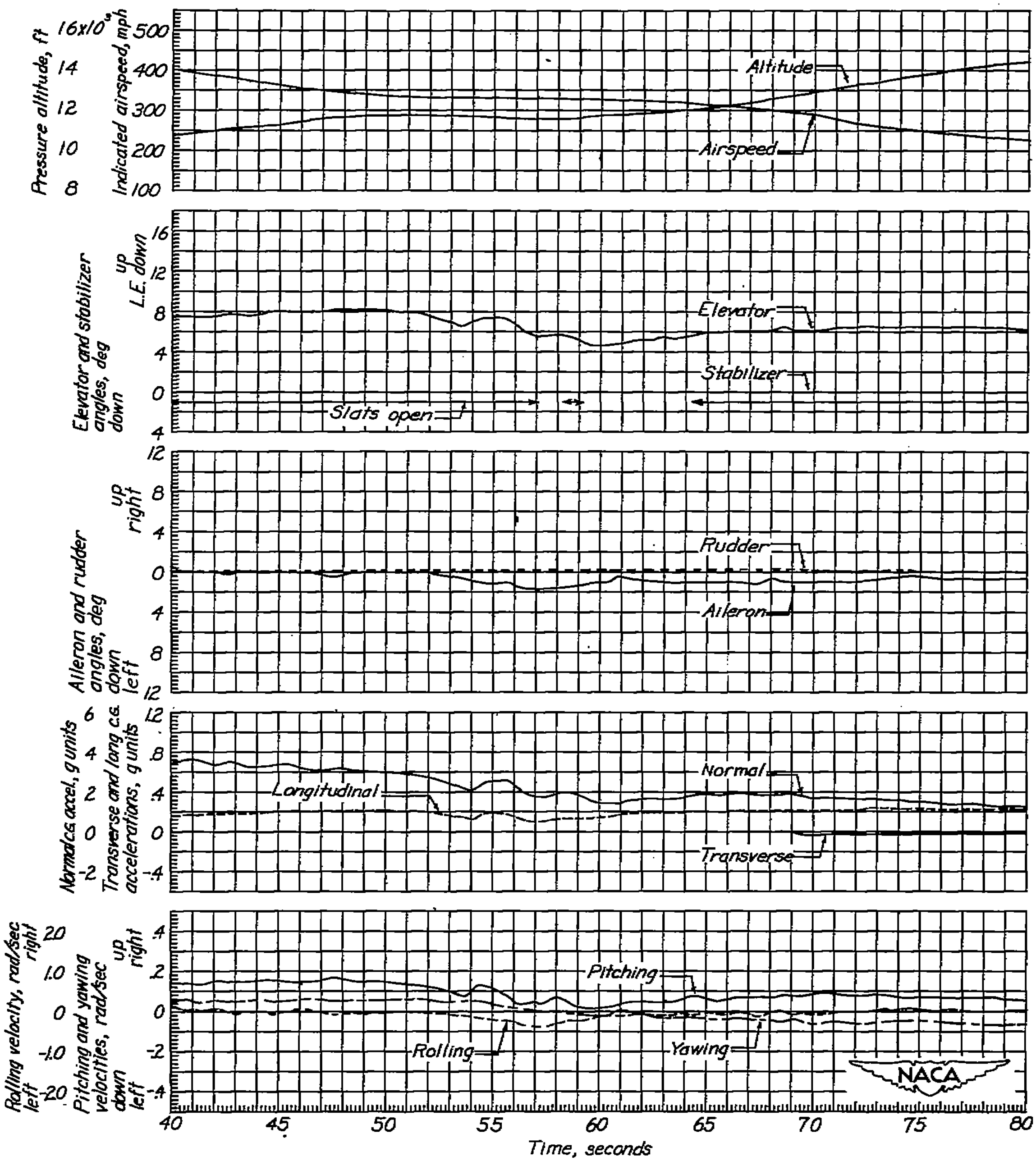


Figure 13.- Diving turn and pull-out followed by climbing turns. Airplane weight, 13,100 pounds; center of gravity at 23.1-percent mean aerodynamic chord.



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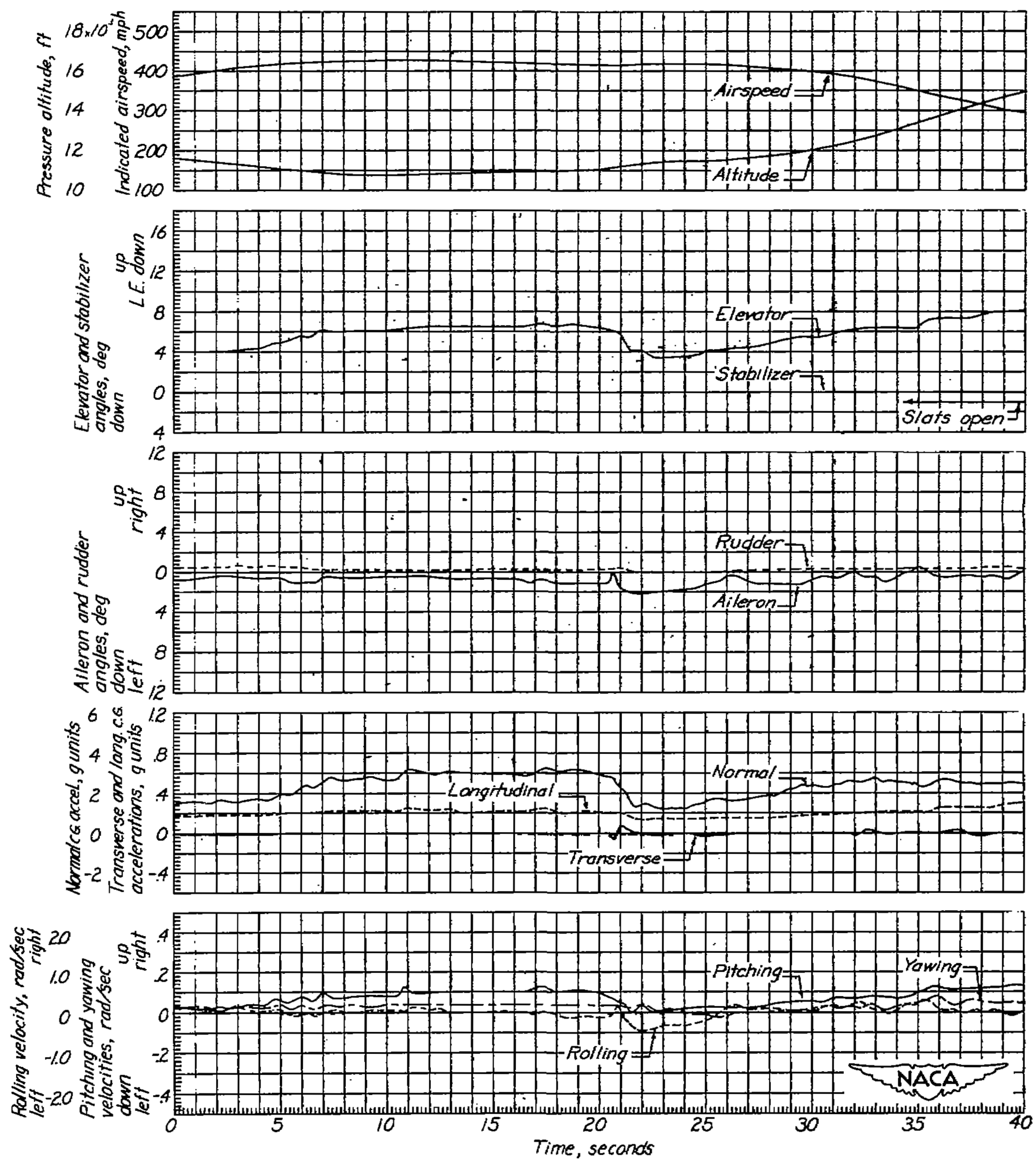

Figure 14.- Climbing turns. Airplane weight, 13,000 pounds; center of gravity at 23.1-percent mean aerodynamic chord.

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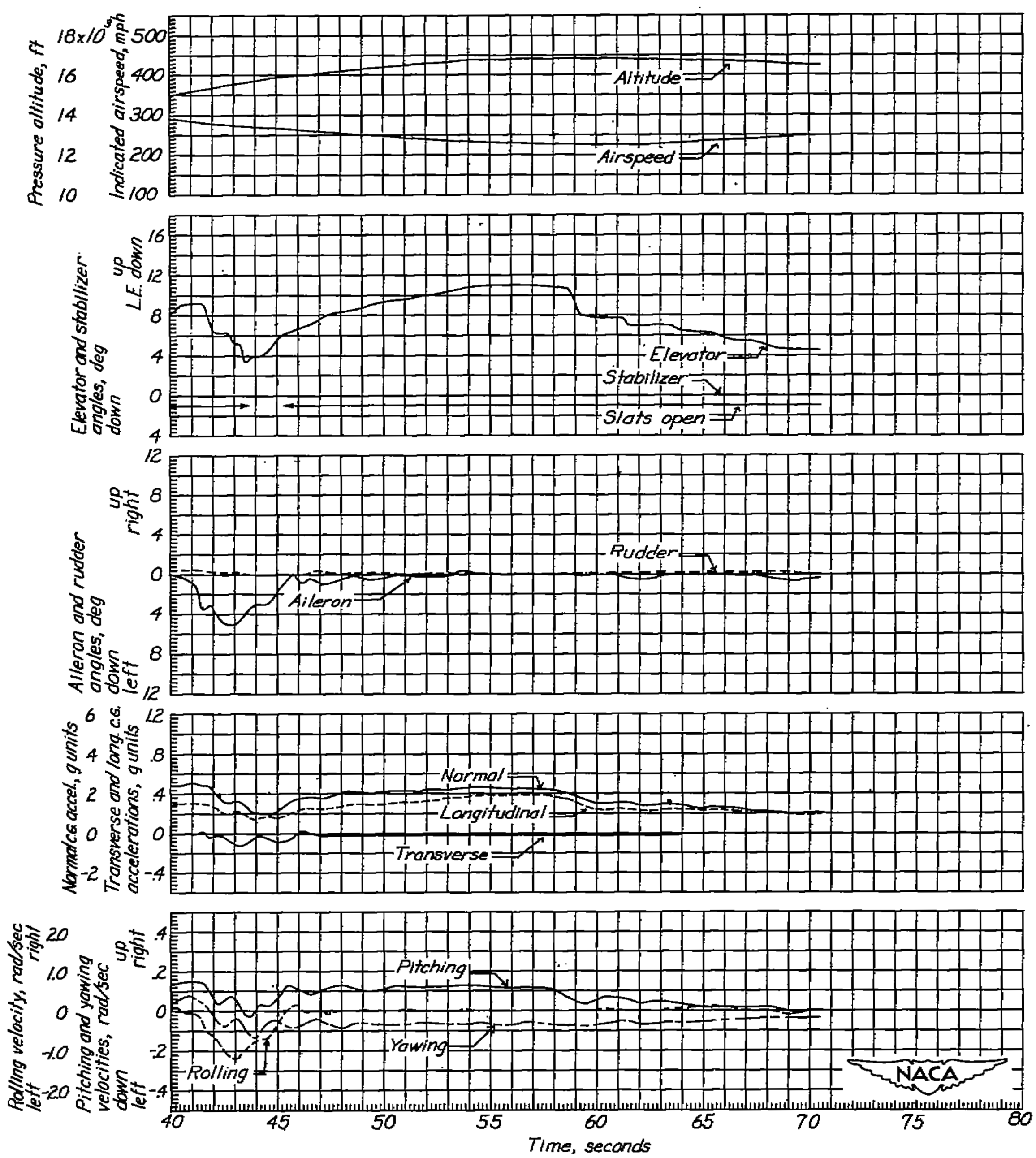

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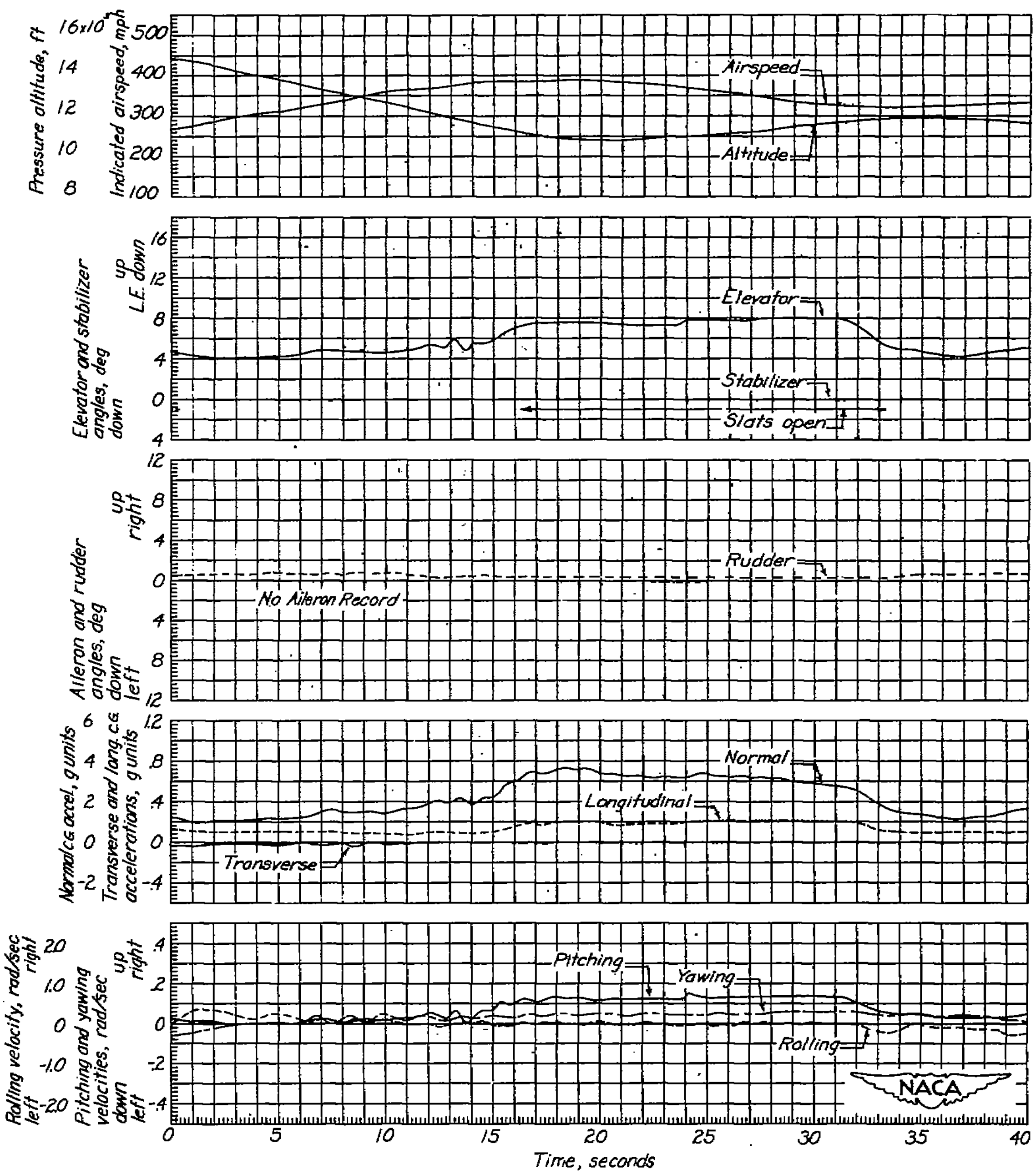

Figure 15.- Dive, pull-out, and climbing turns. Airplane weight, 12,700 pounds; center of gravity at 23.2-percent mean aerodynamic chord.

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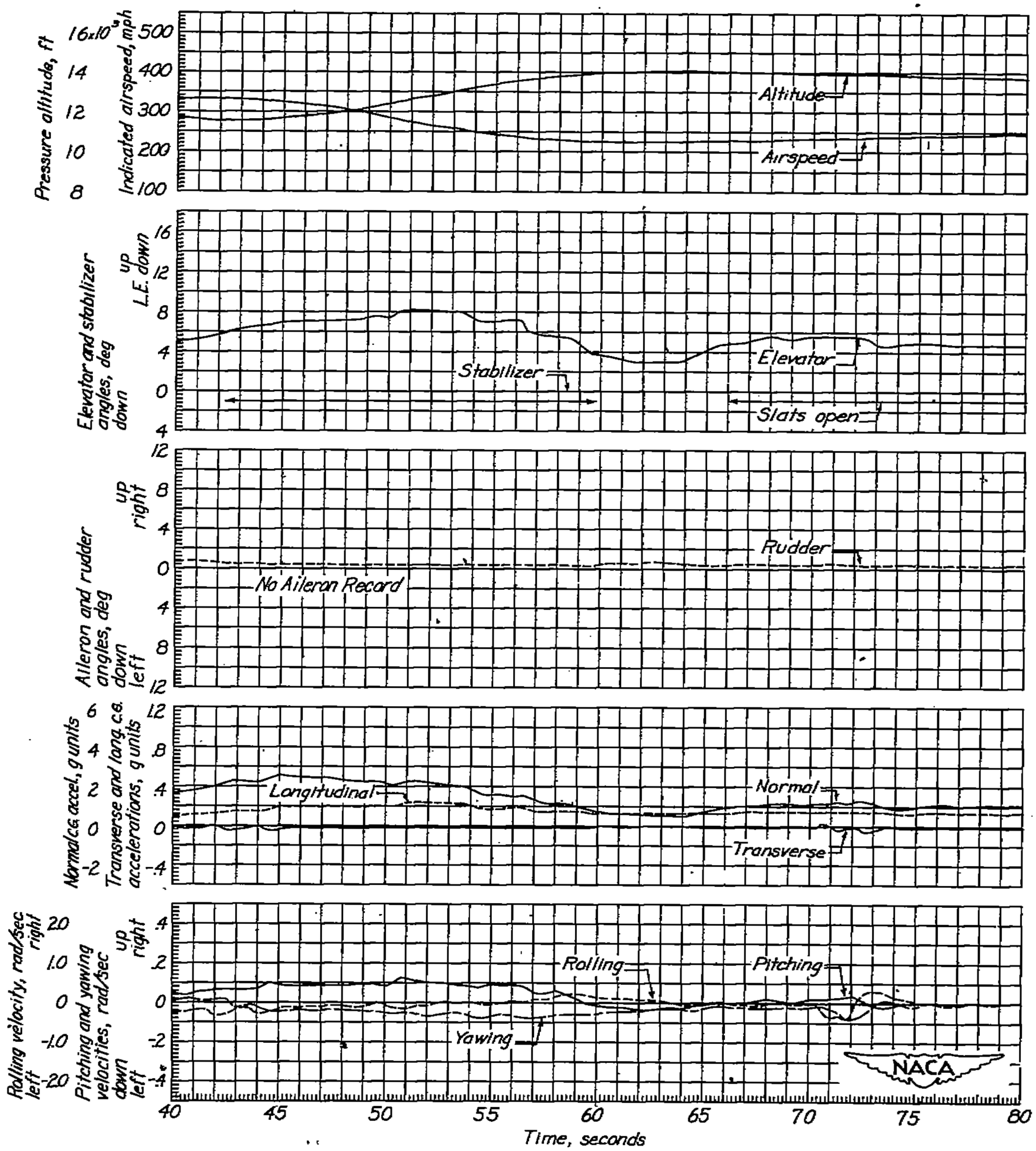

Figure 15.- Concluded.

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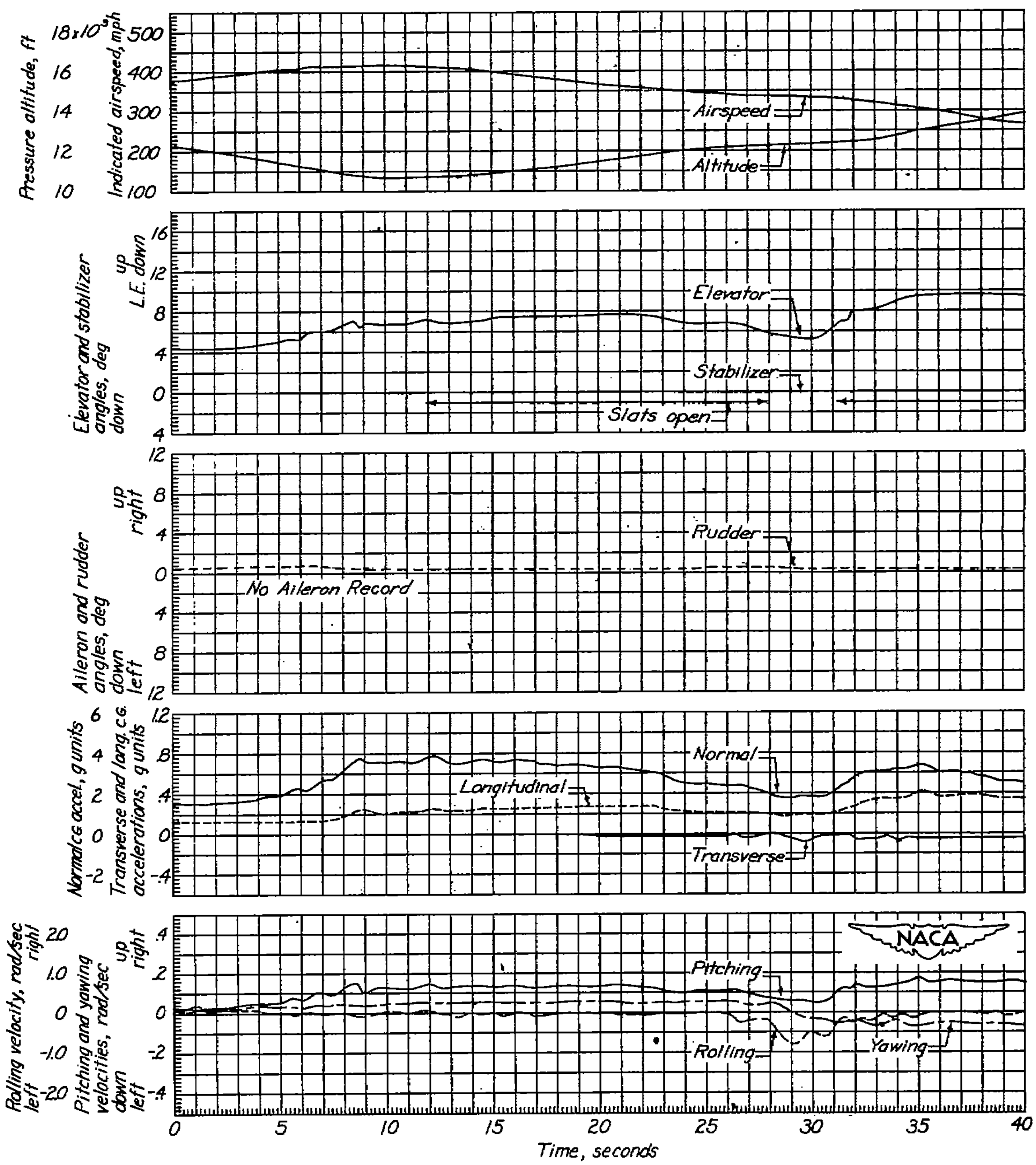
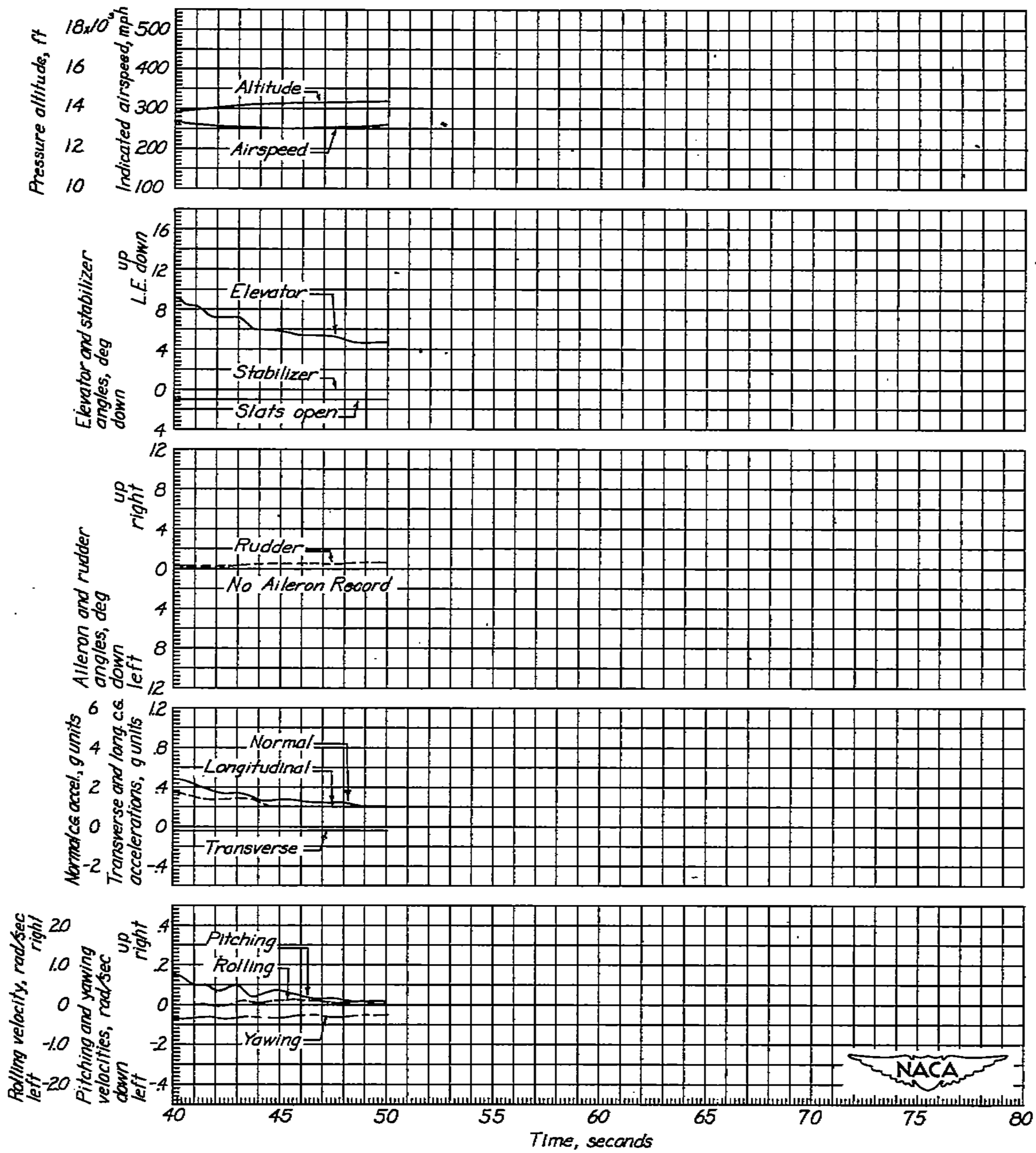


Figure 16.- Dive, pull-out, and climbing turns. Airplane weight, 12,500 pounds; center of gravity at 23.3-percent mean aerodynamic chord.



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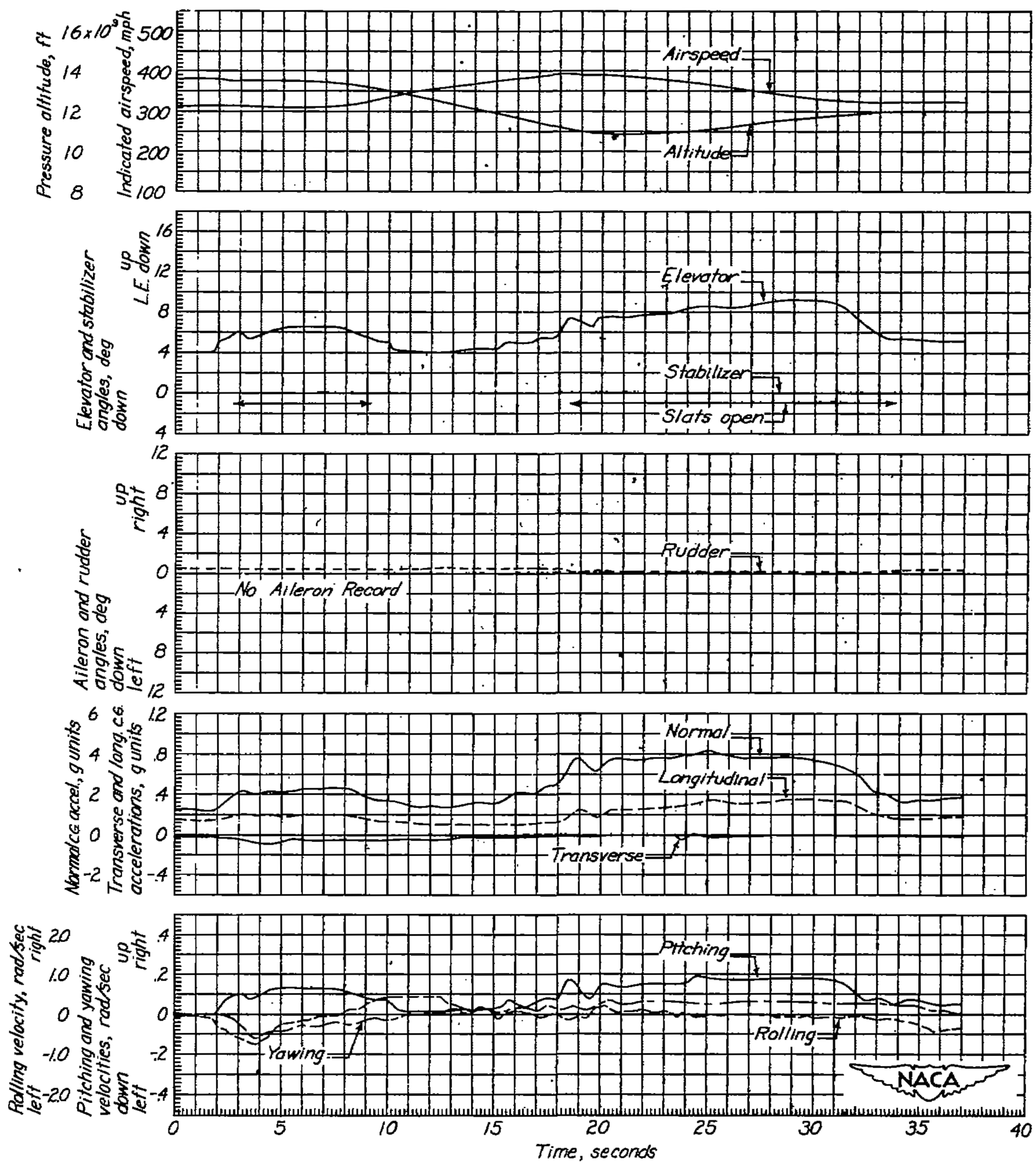


Figure 17.- Turn entry into a dive and pull-out. Airplane weight, 12,450 pounds; center of gravity at 23.3-percent mean aerodynamic chord.

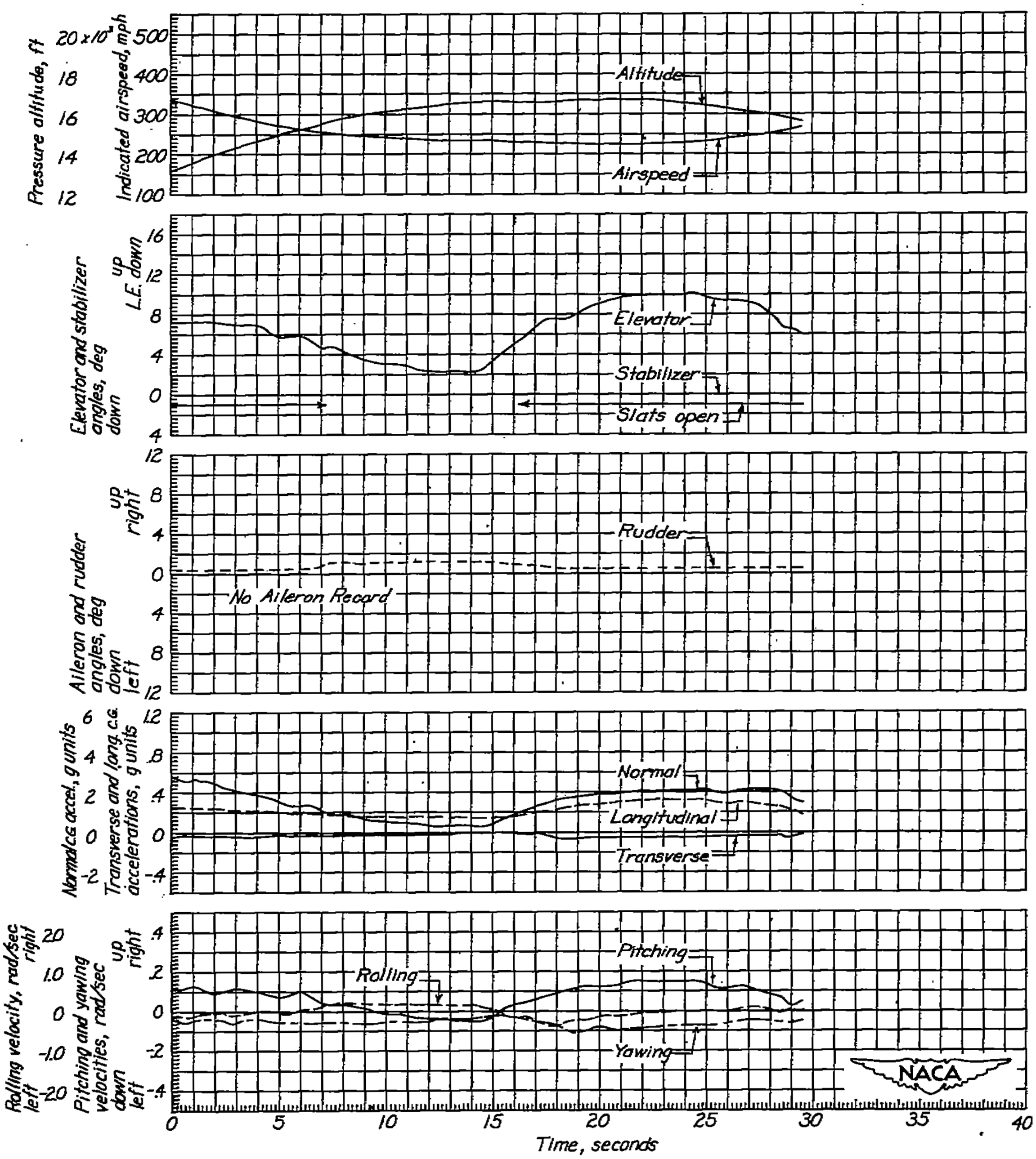


Figure 18.- Chandelle followed by a turn. Airplane weight, 12,100 pounds; center of gravity at 23.5-percent mean aerodynamic chord.

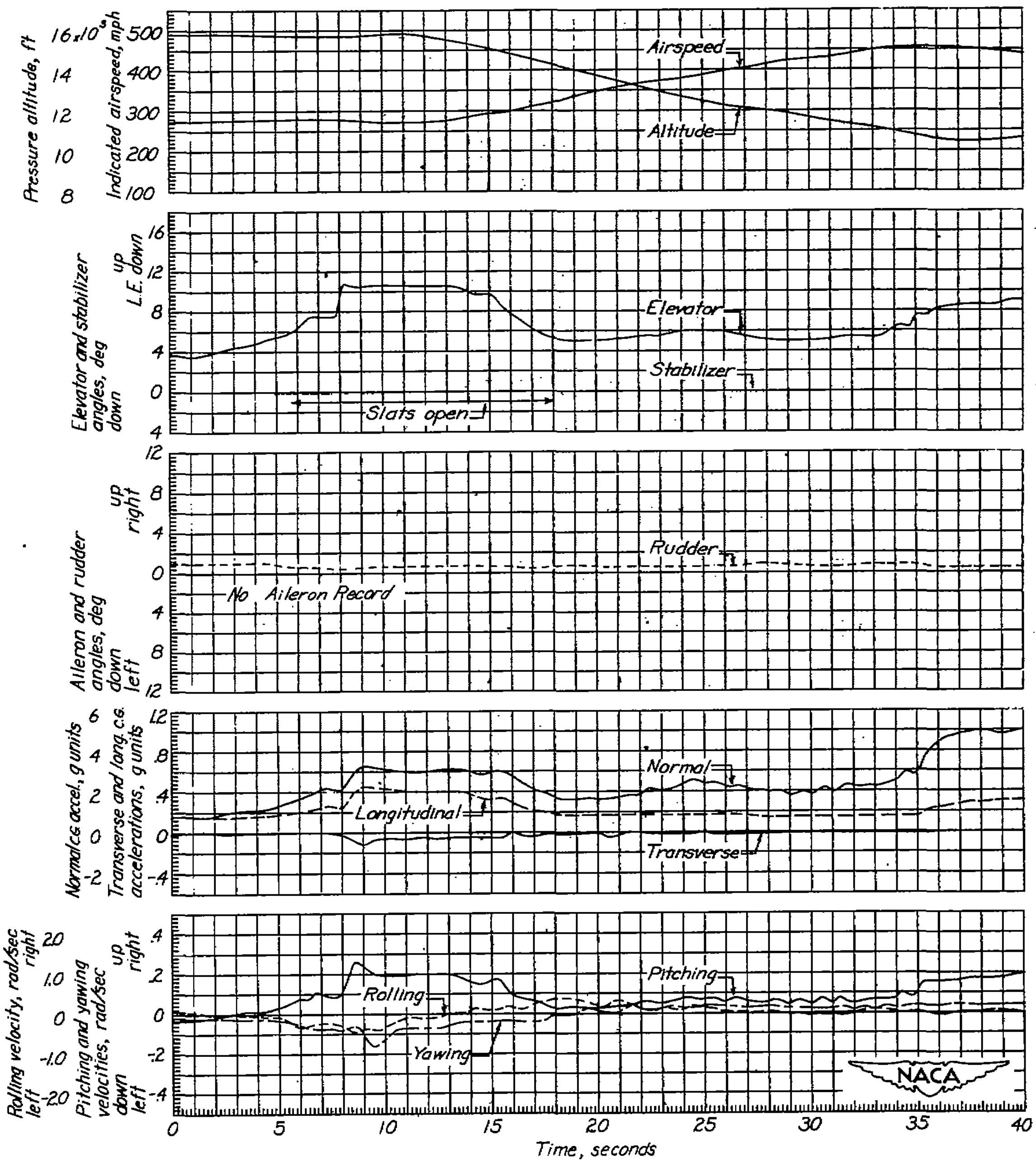
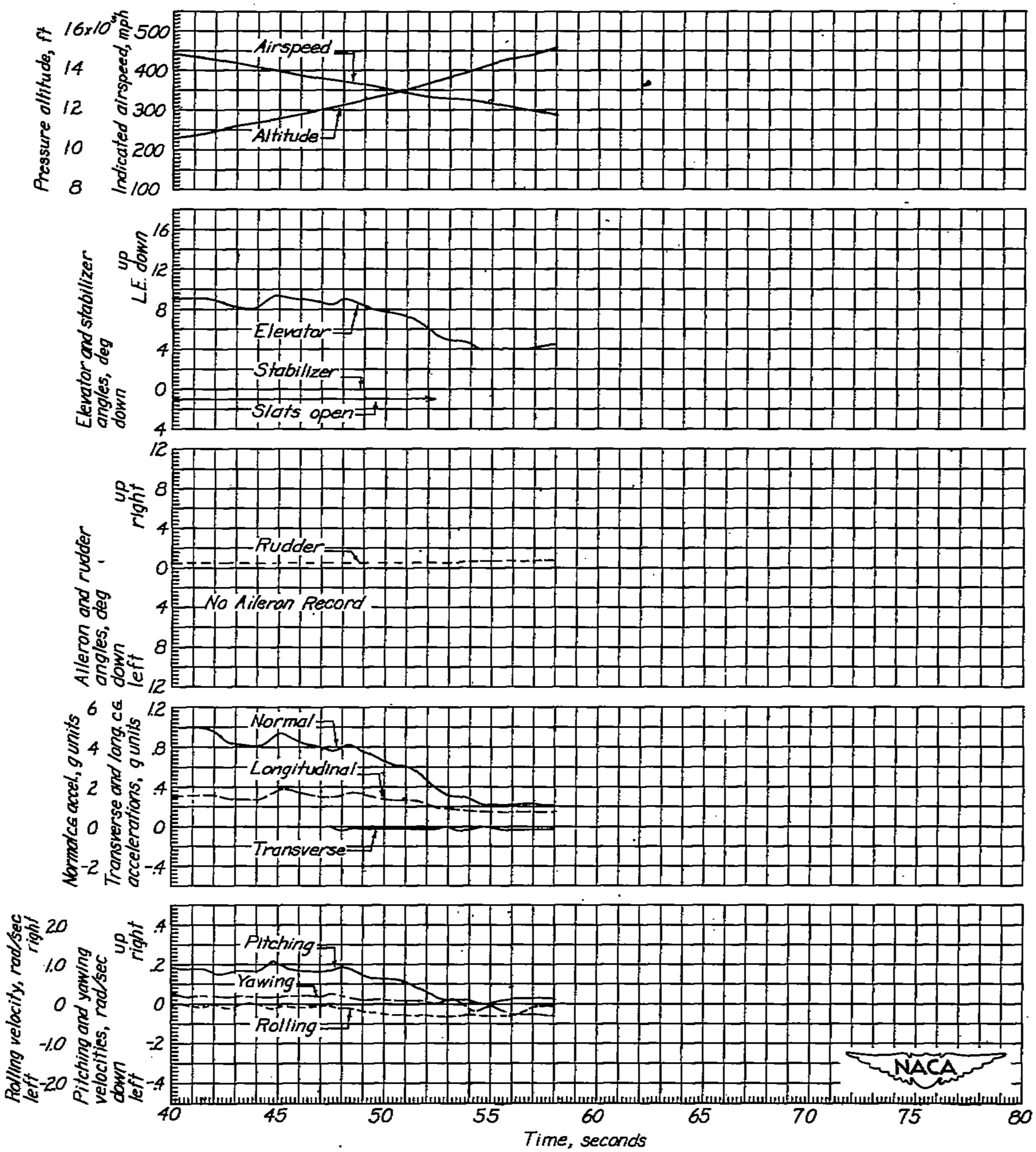


Figure 19.- Turn entry into a dive and pull-up into a climbing turn. Airplane weight, 12,000 pounds; center of gravity at 23.5-percent mean aerodynamic chord.



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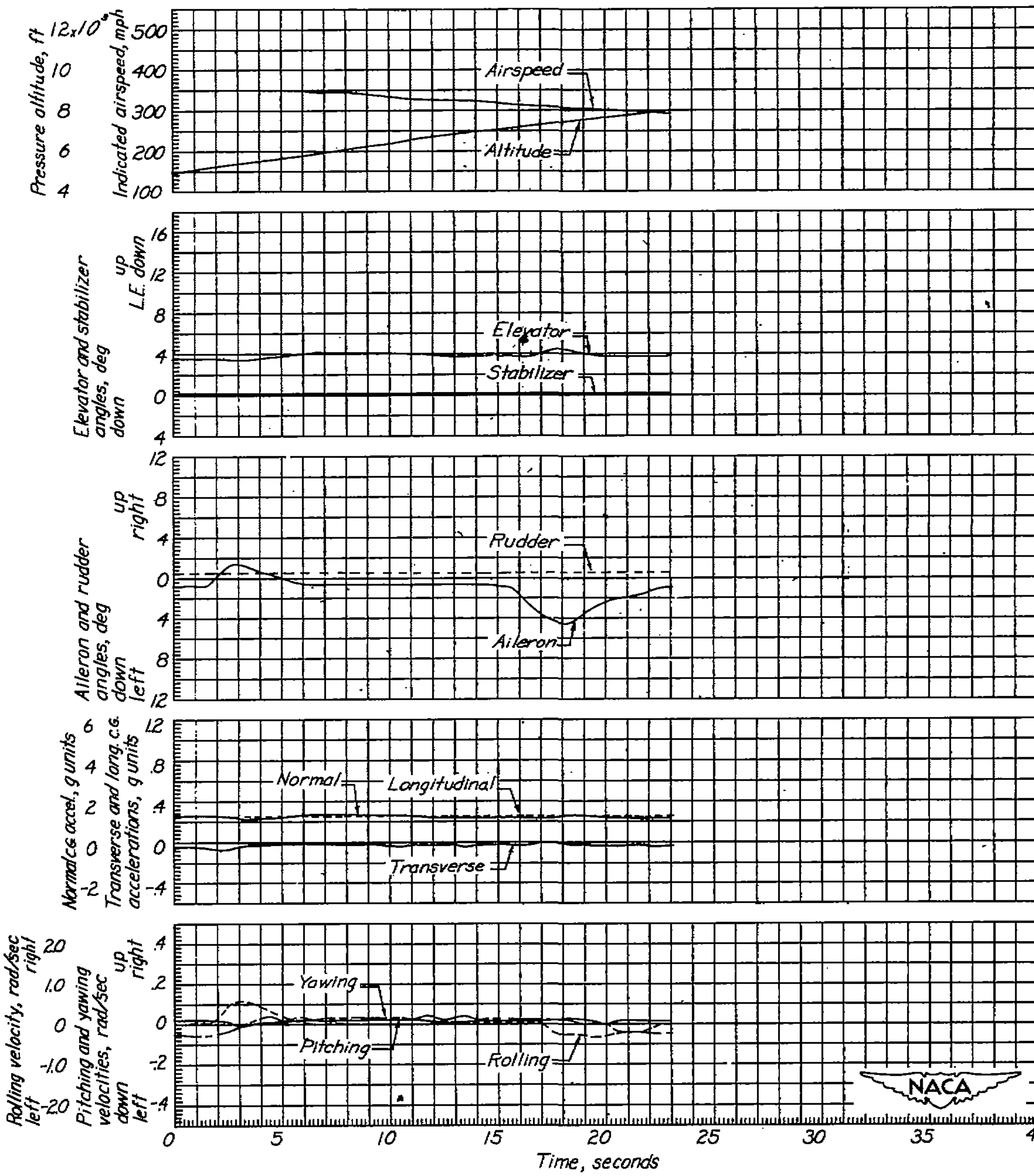


Figure 20.- Gentle climbing turns. Airplane weight, 13,000 pounds; center of gravity at 23.1-percent mean aerodynamic chord.

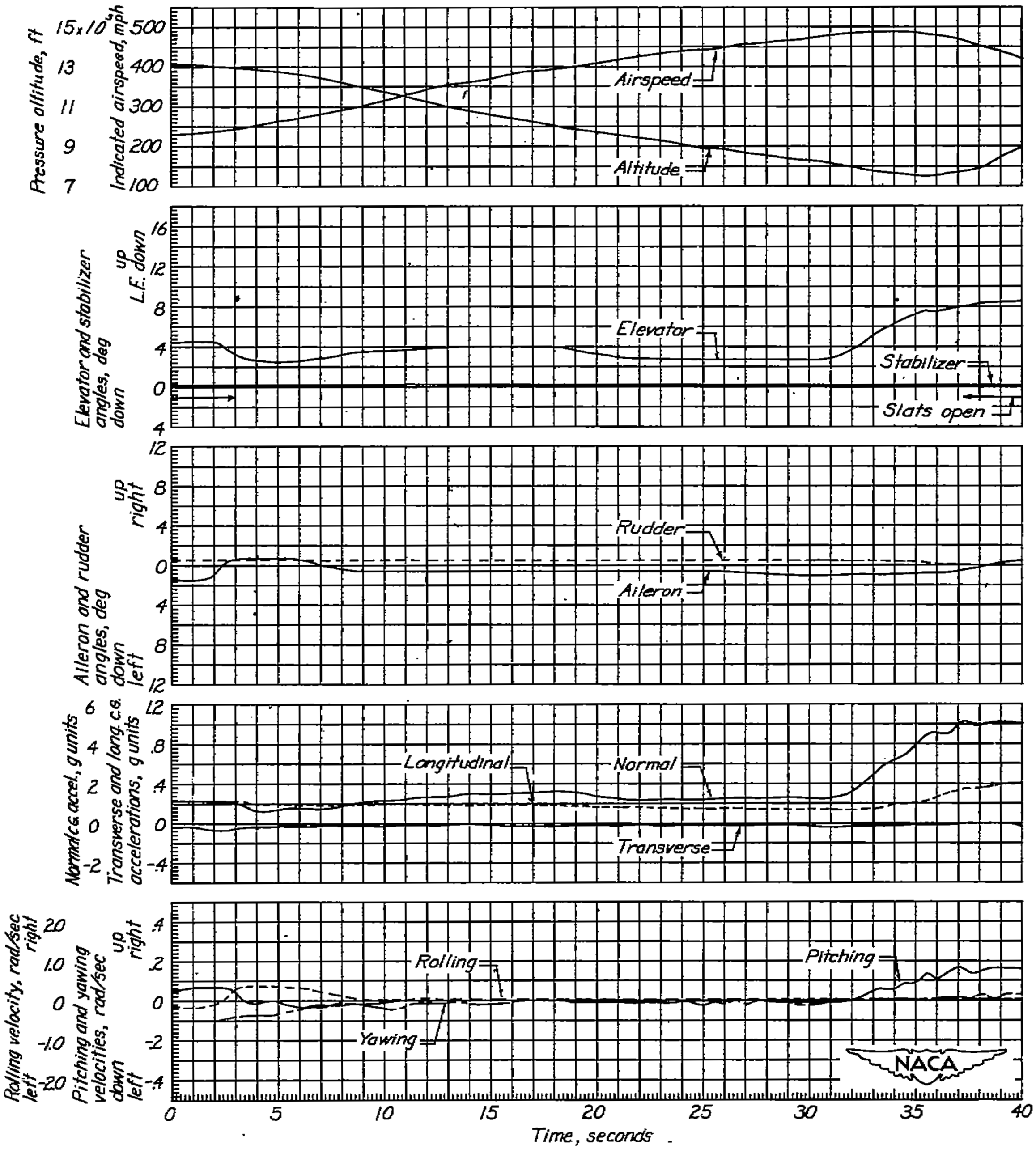
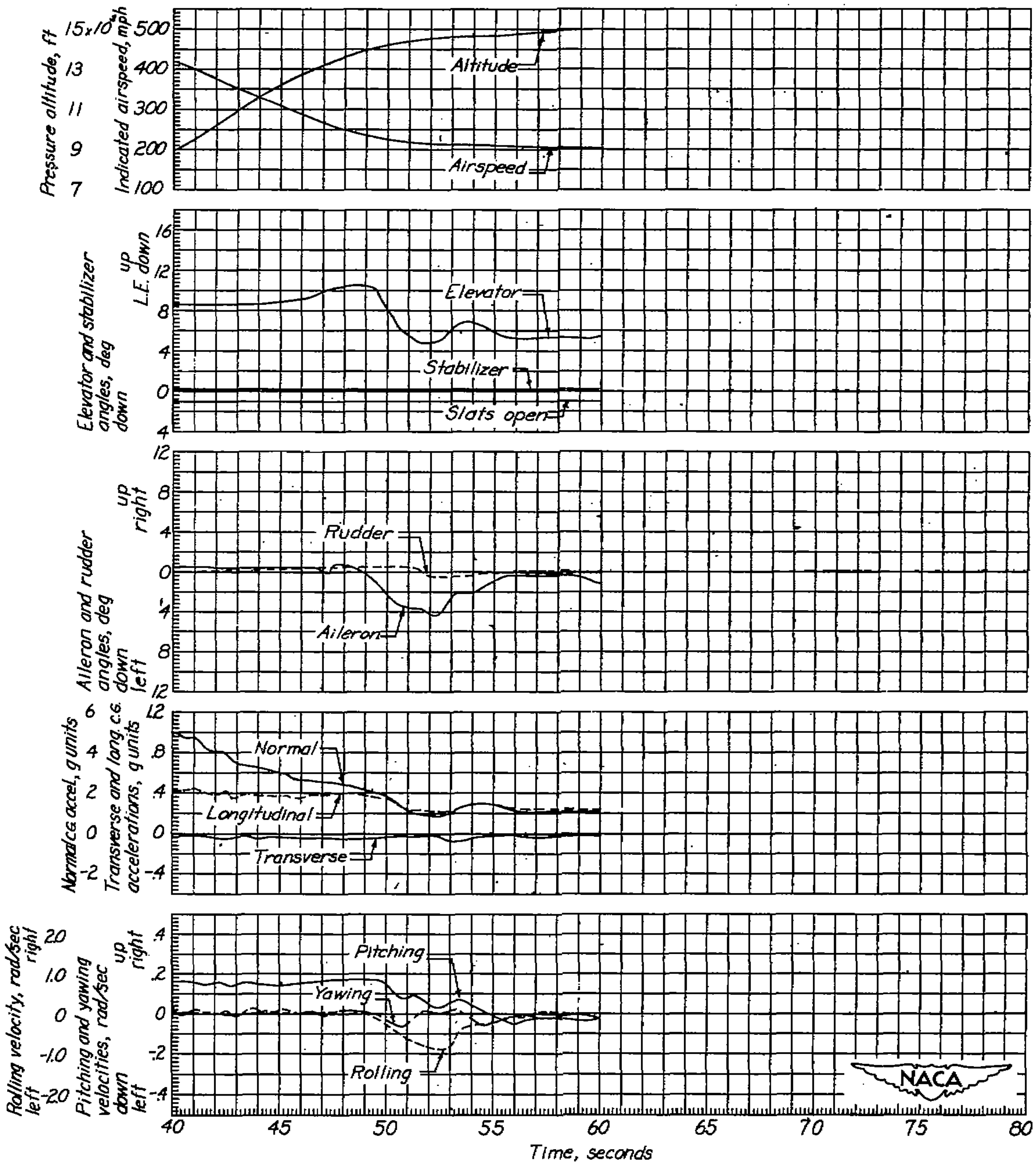


Figure 21.- Turn entry into a dive and pull-up into an Immelman turn. Airplane weight, 13,050 pounds; center of gravity at 23.1-percent mean aerodynamic chord.



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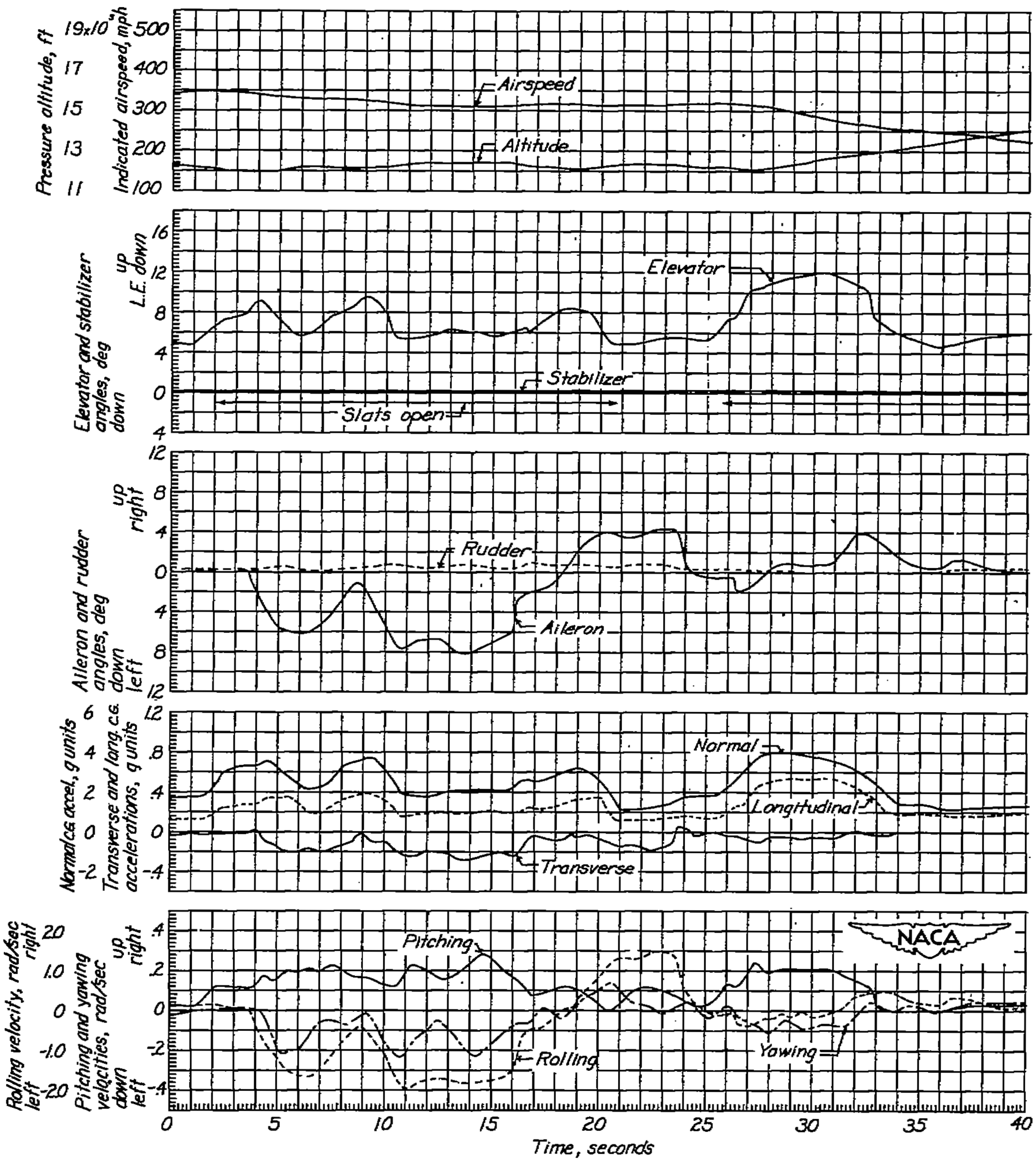


Figure 22.- Barrel rolls followed by abrupt pull-up. Airplane weight, 13,000 pounds; center of gravity at 23.1-percent mean aerodynamic chord.

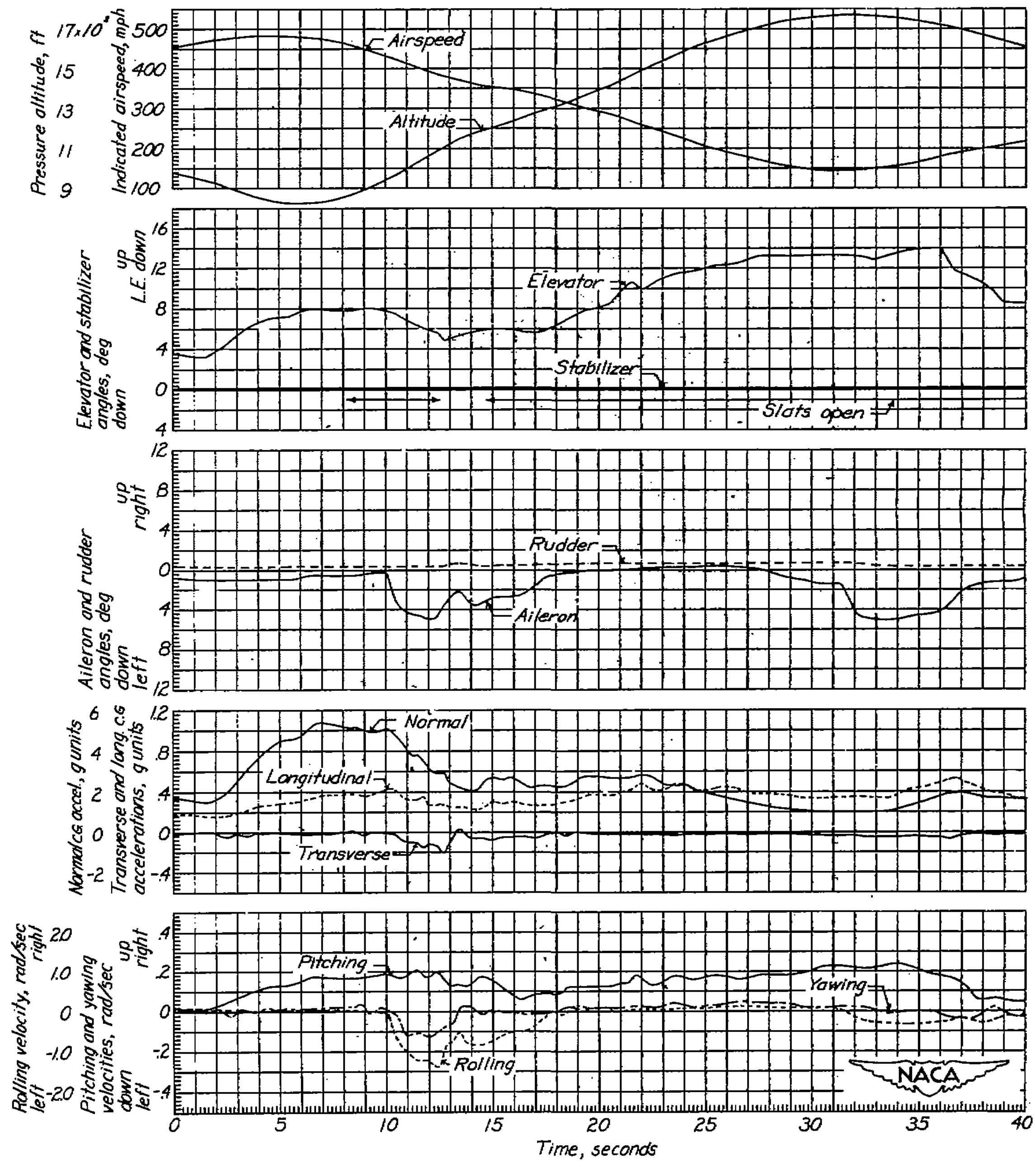
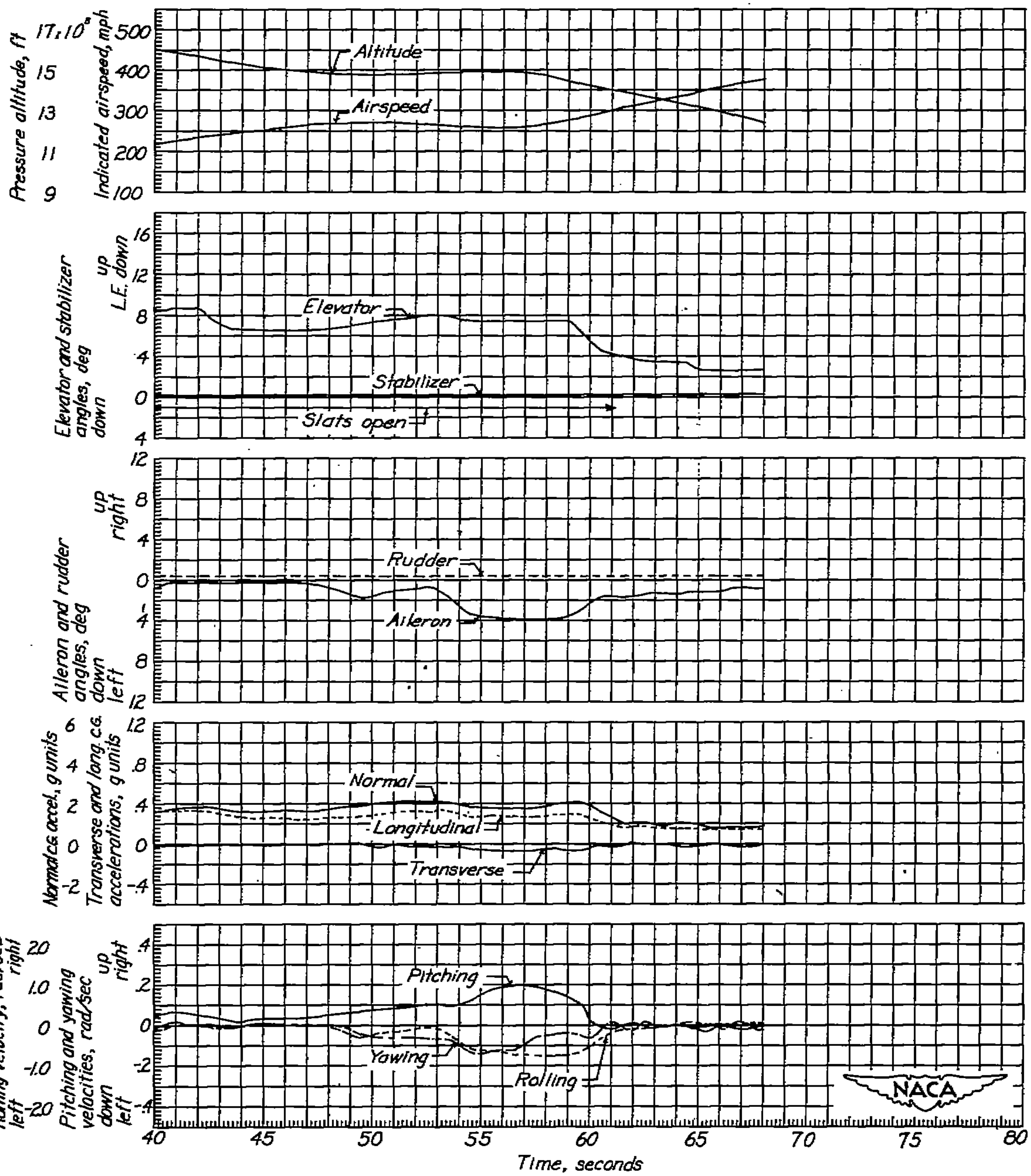


Figure 23.- Pull-up into a barrel-roll climb followed by a chandelle and a slow roll. Airplane weight, 12,95? pounds, center of gravity at 23.1-percent mean aerodynamic chord.



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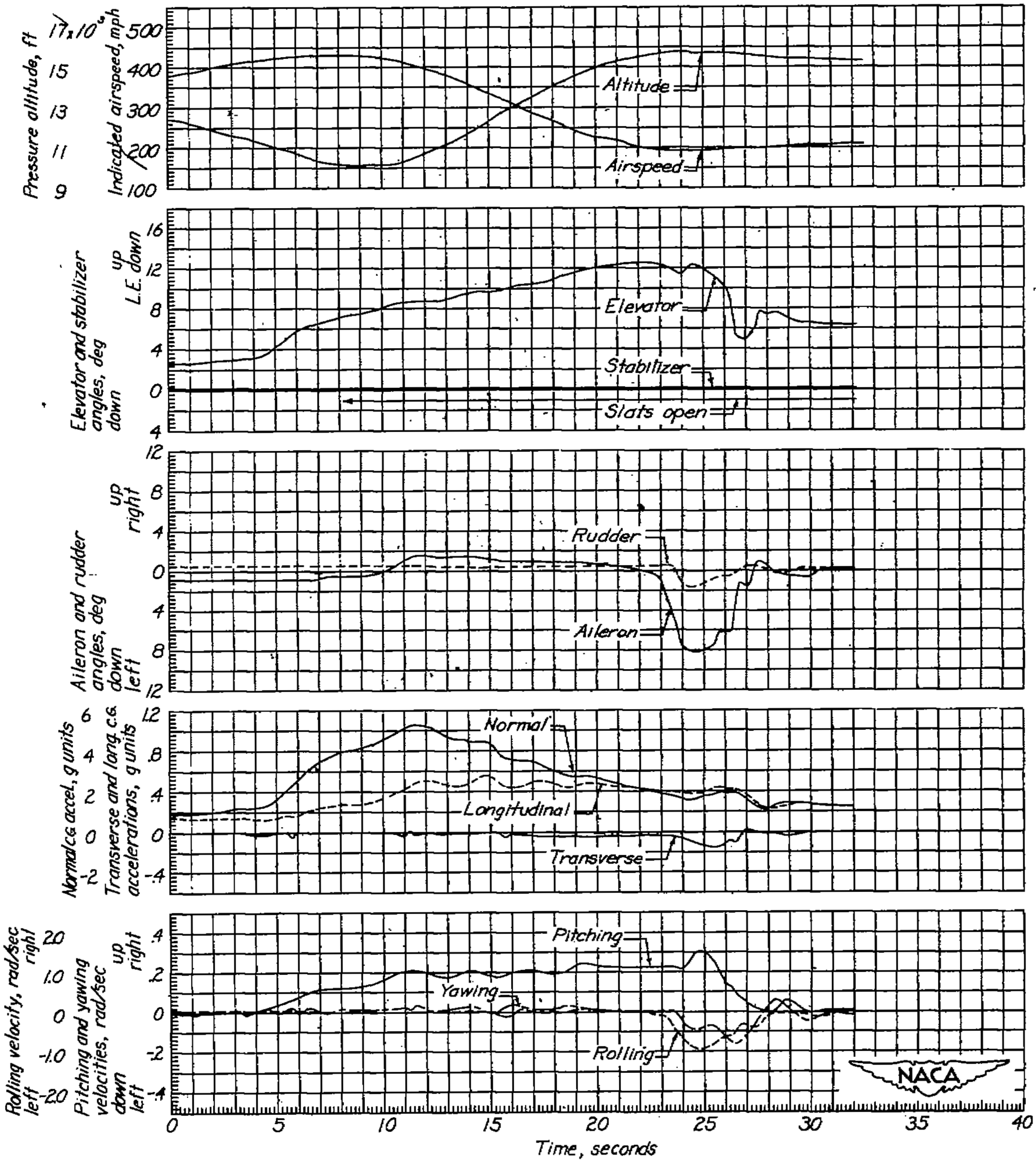


Figure 24.- Immelman turn. Airplane weight, 12,900 pounds; center of gravity at 23.1-percent mean aerodynamic chord.

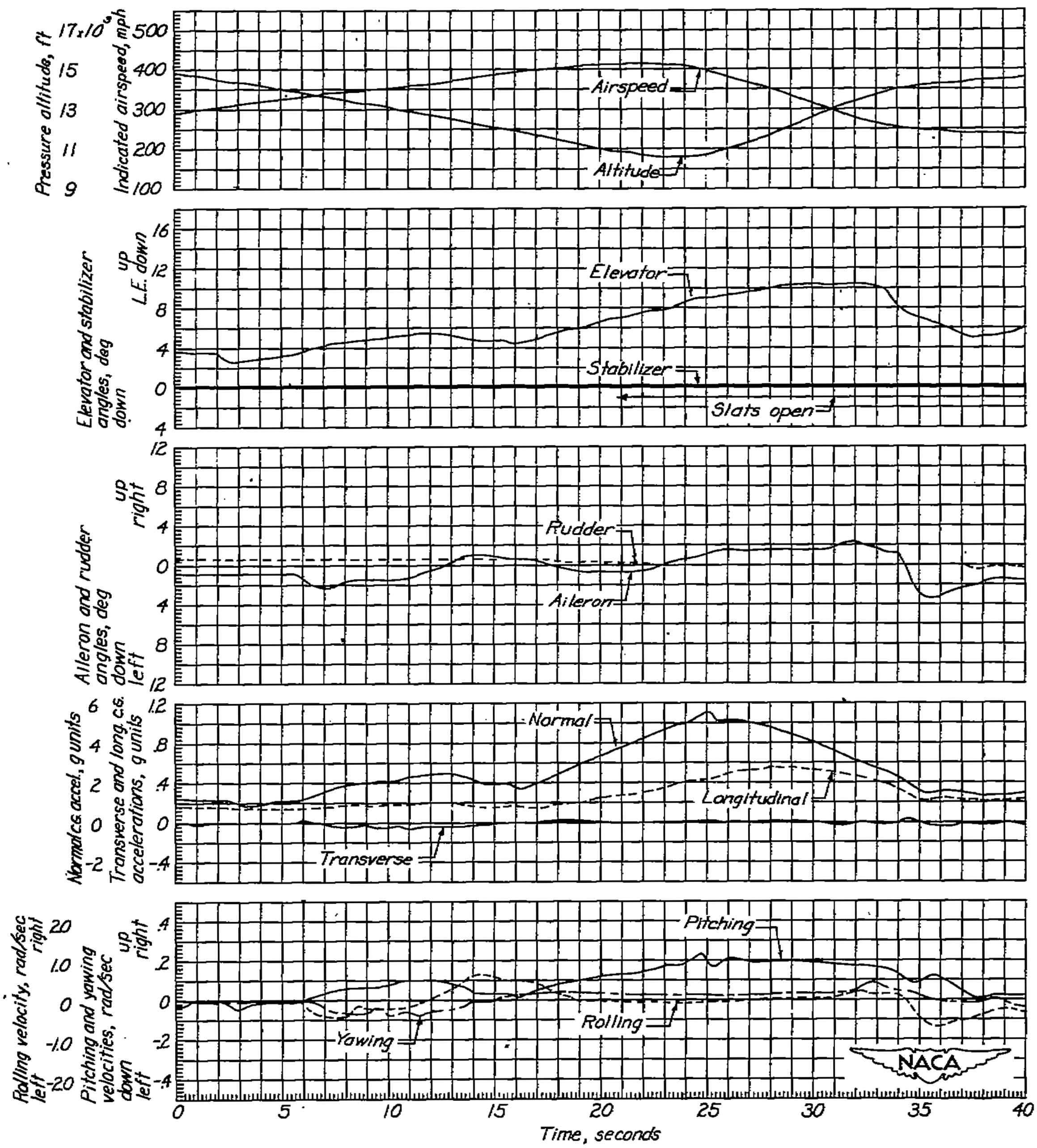


Figure 25.- Diving turns followed by a chandelle. Airplane weight, 12,850 pounds; center of gravity at 23.1-percent mean aerodynamic chord.

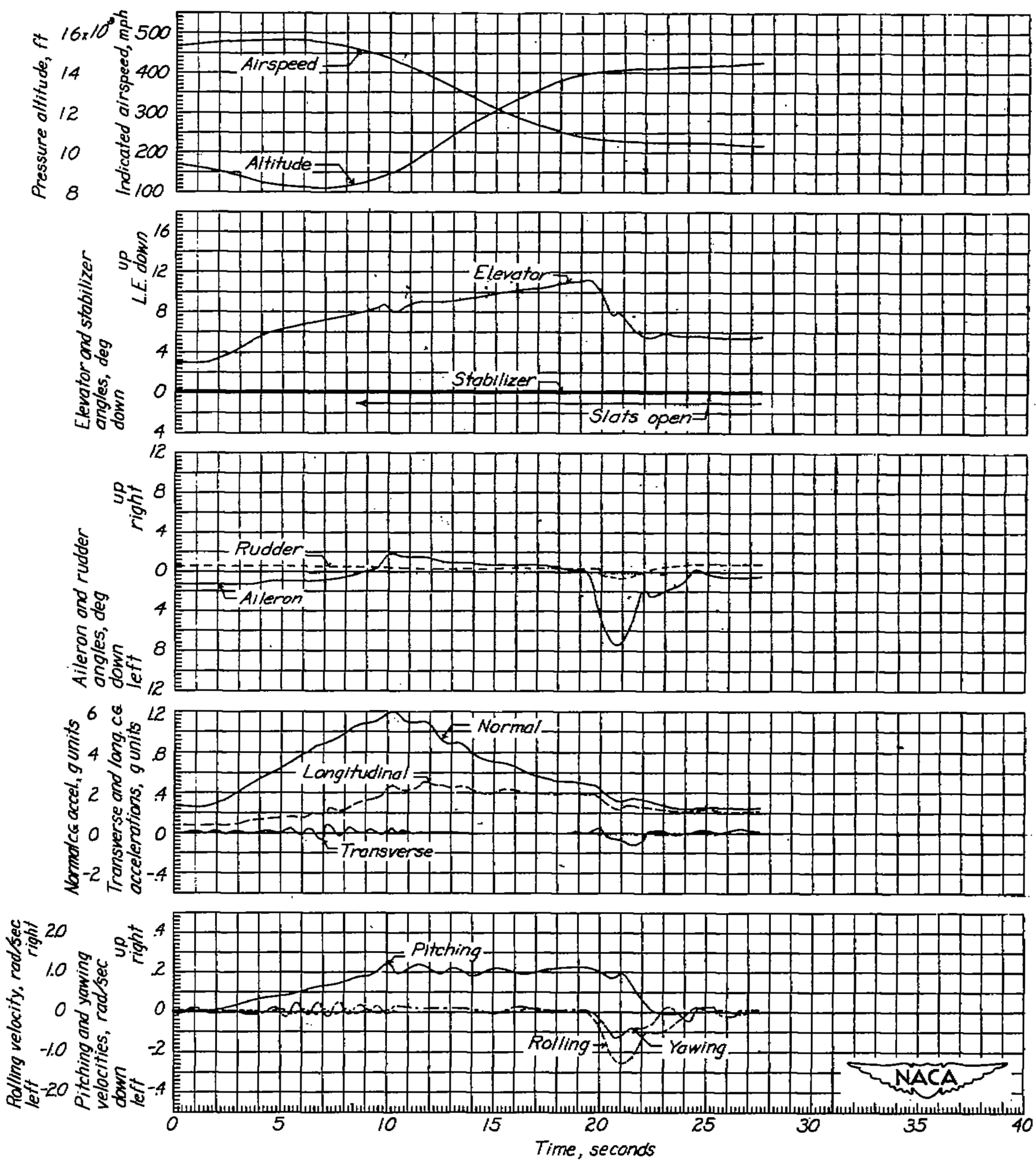


Figure 26.- Immelman turn. Airplane weight, 12,800 pounds; center of gravity at 23.2-percent mean aerodynamic chord.

[redacted]

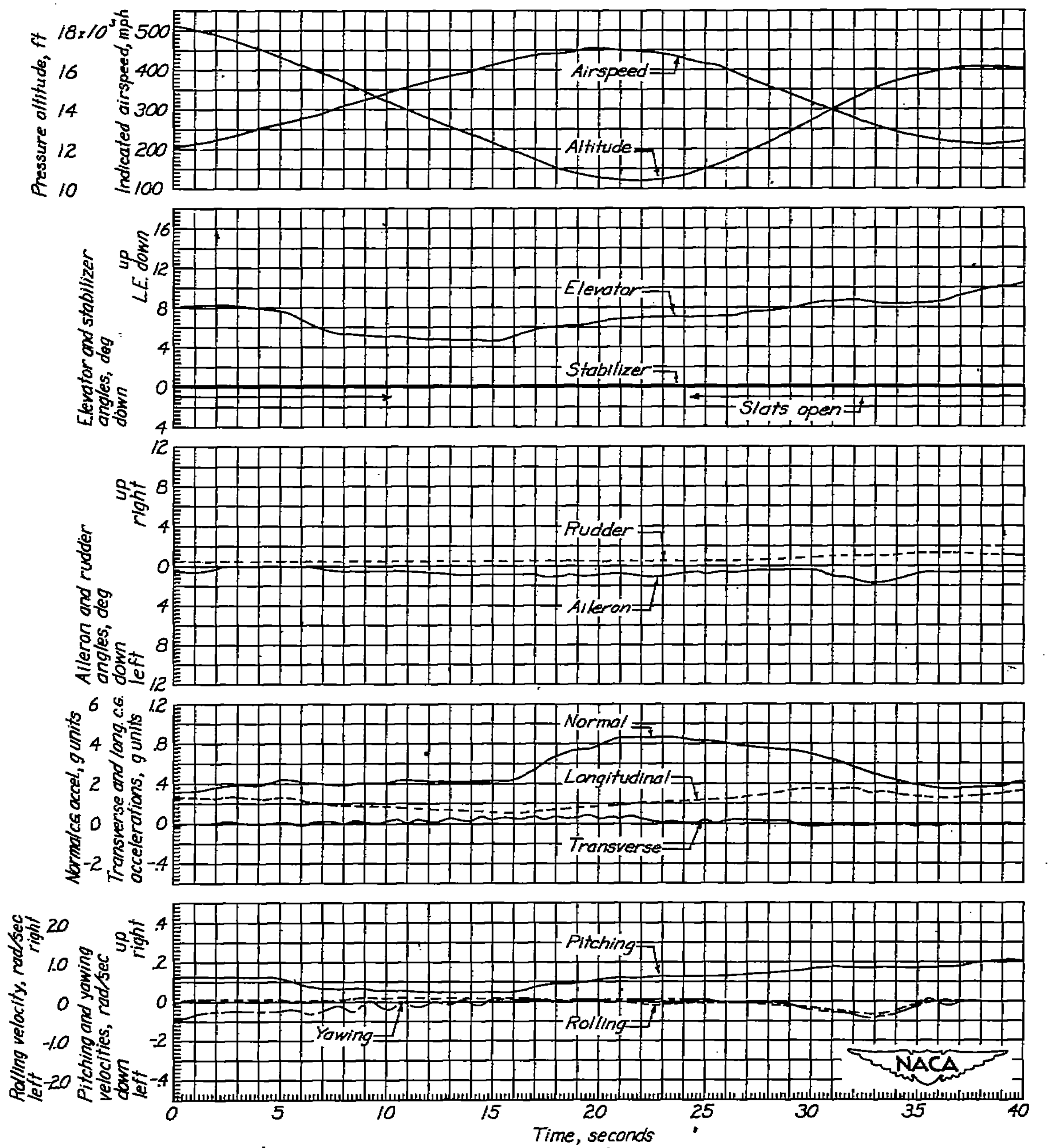
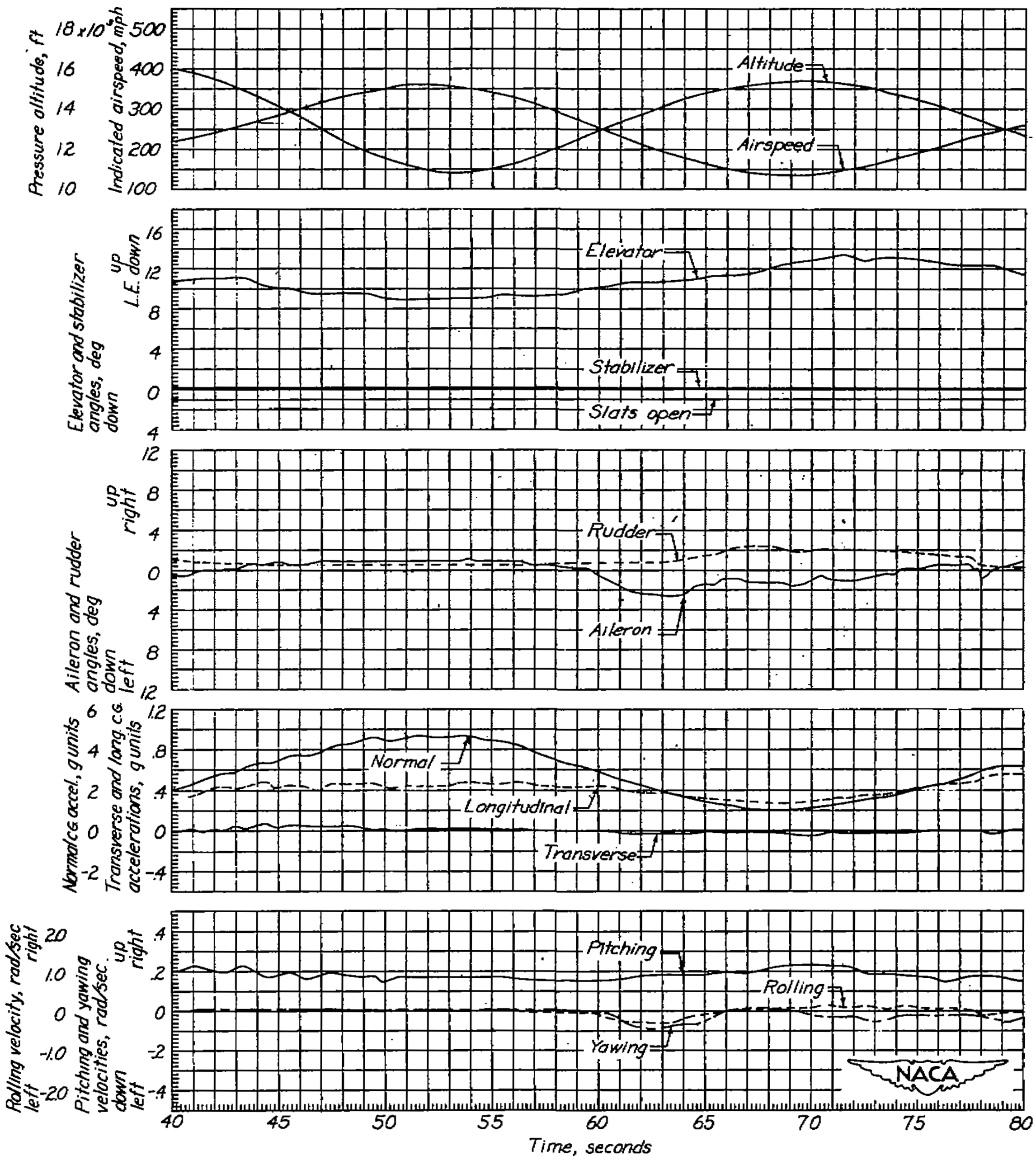


Figure 27.- Diving turn and pull-out, quarter-roll entry into a loop ... and repeat. Airplane weight, 12,750 pounds; center of gravity at 23.2-percent mean aerodynamic chord.



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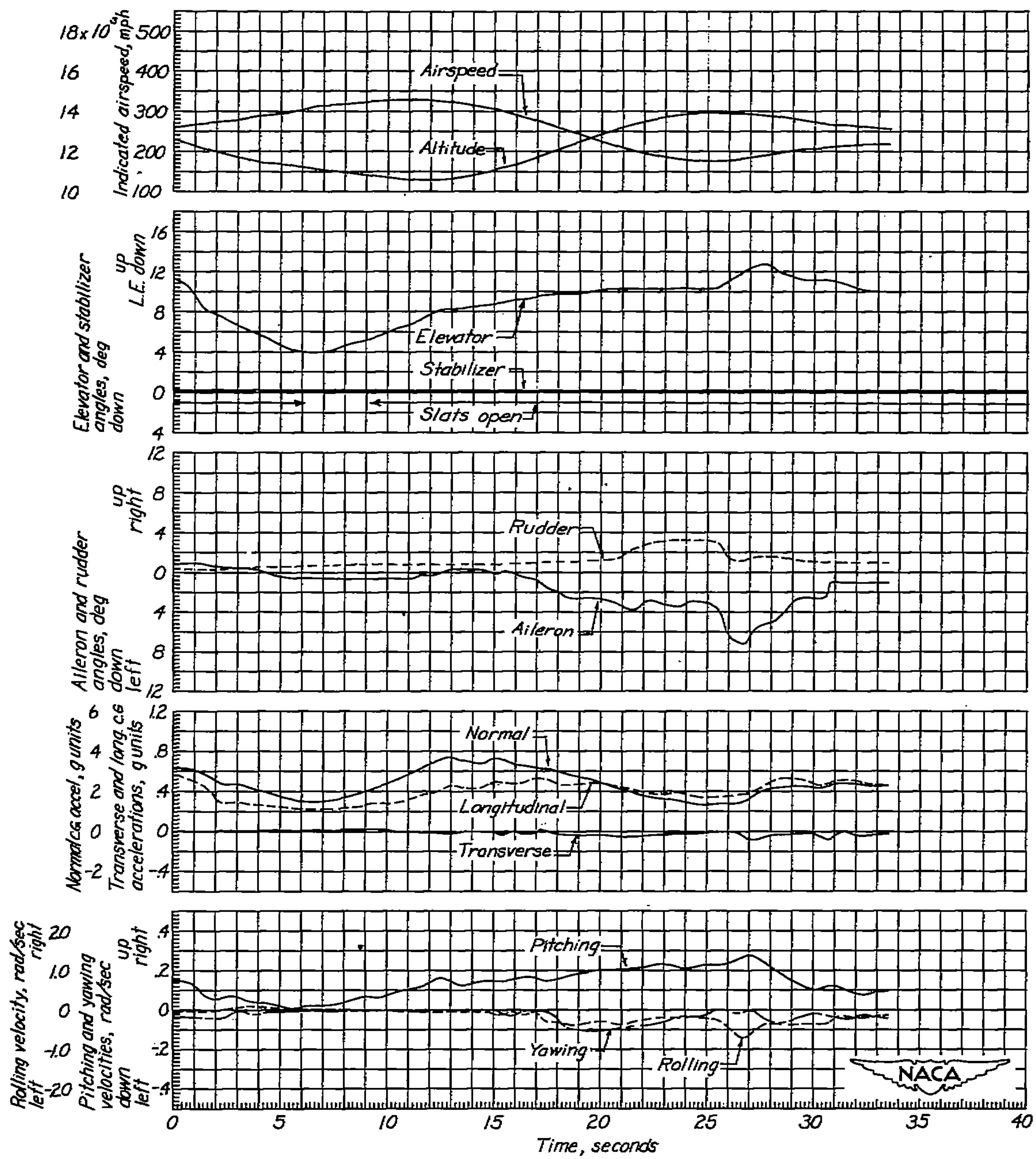

Figure 28.- Dive, pull-out, and barrel roll. Airplane weight, 12,700 pounds; center of gravity 23.2-percent mean aerodynamic chord.

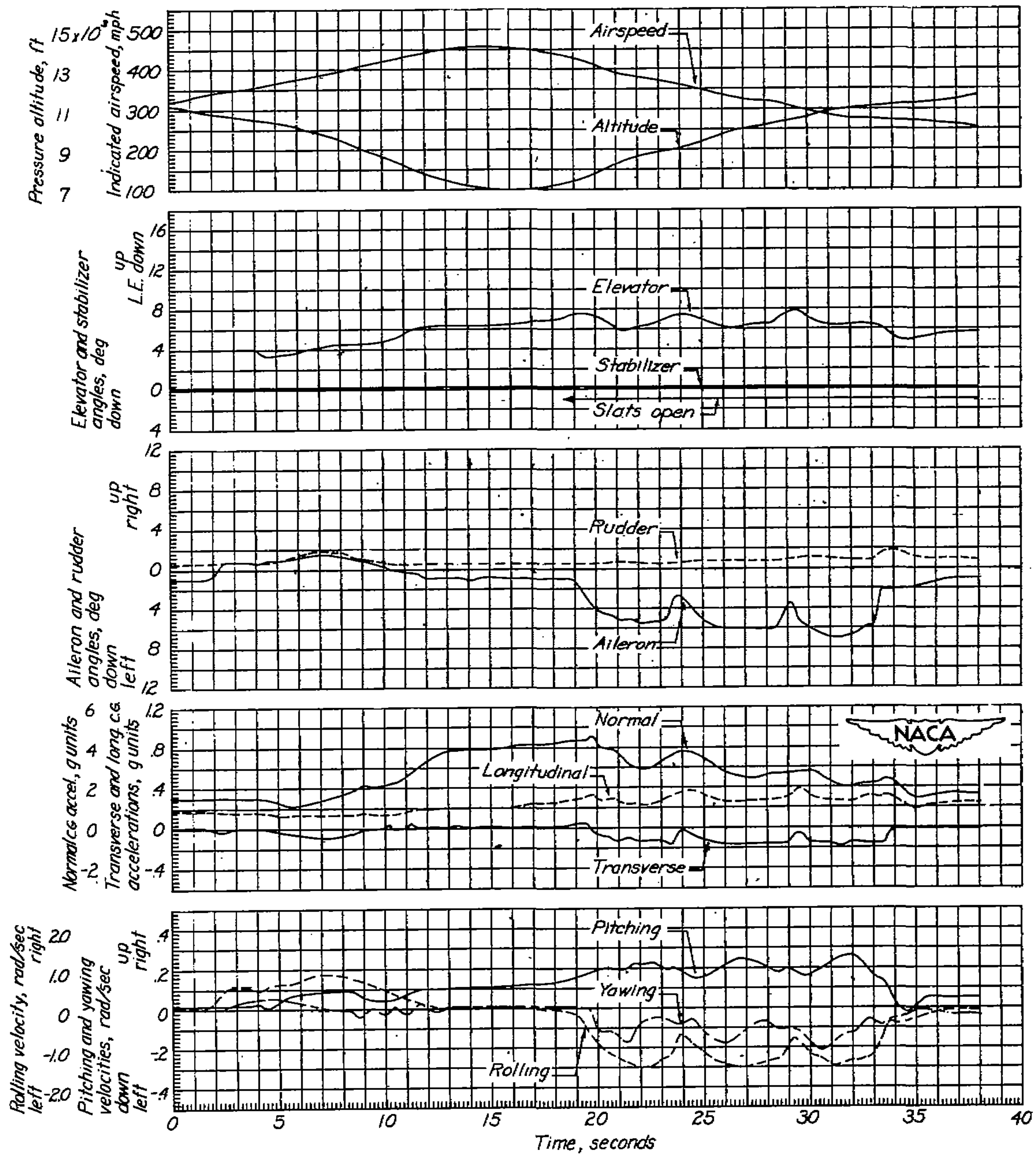

Figure 29.- Roll entry into a dive, pull-out, and barrel rolls. Airplane weight, 12,650 pounds; center of gravity at 23.2-percent mean aerodynamic chord.

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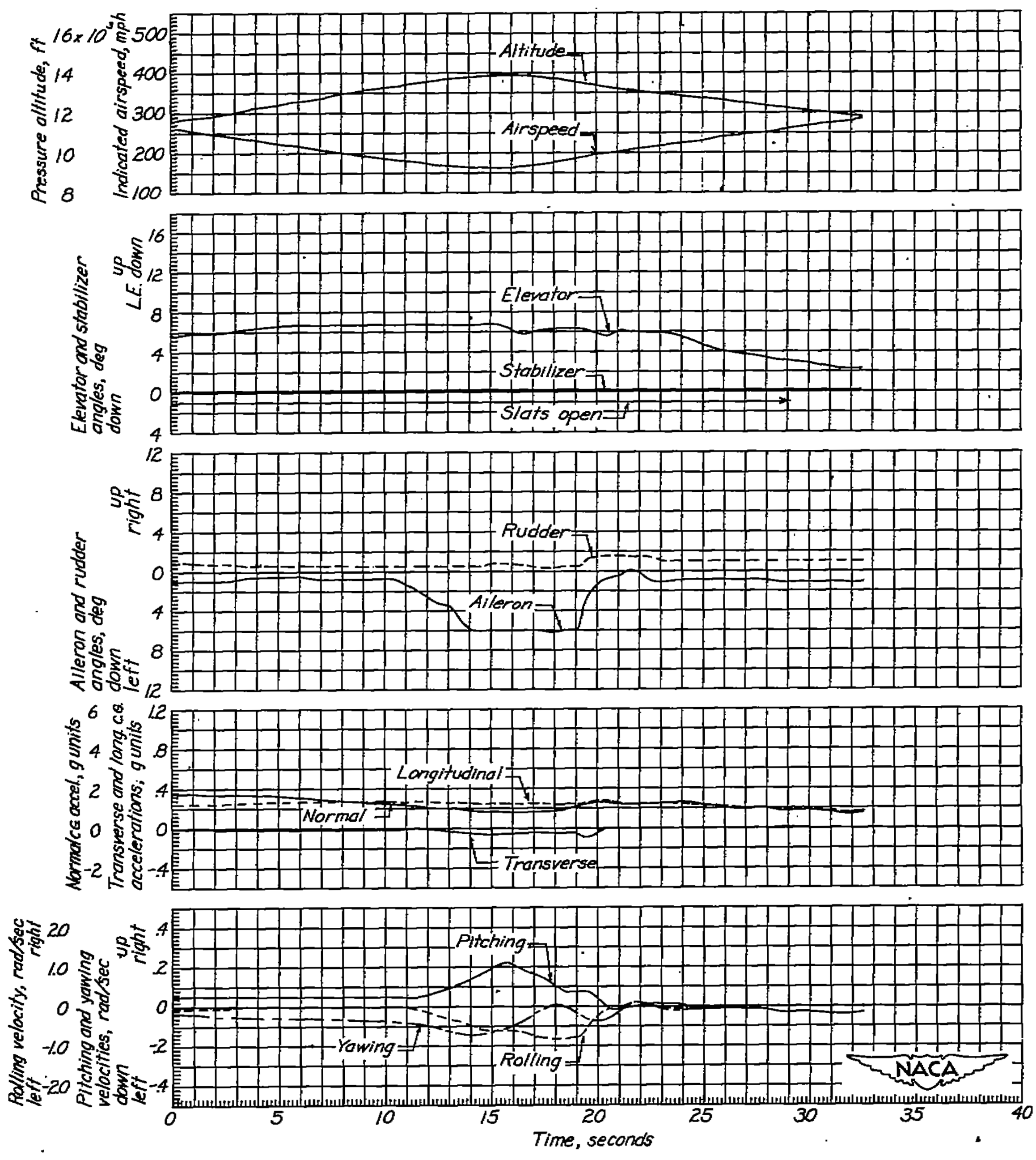

Figure 30.- Slow roll. Airplane weight, 12,650 pounds; center of gravity at 23.2-percent mean aerodynamic chord.

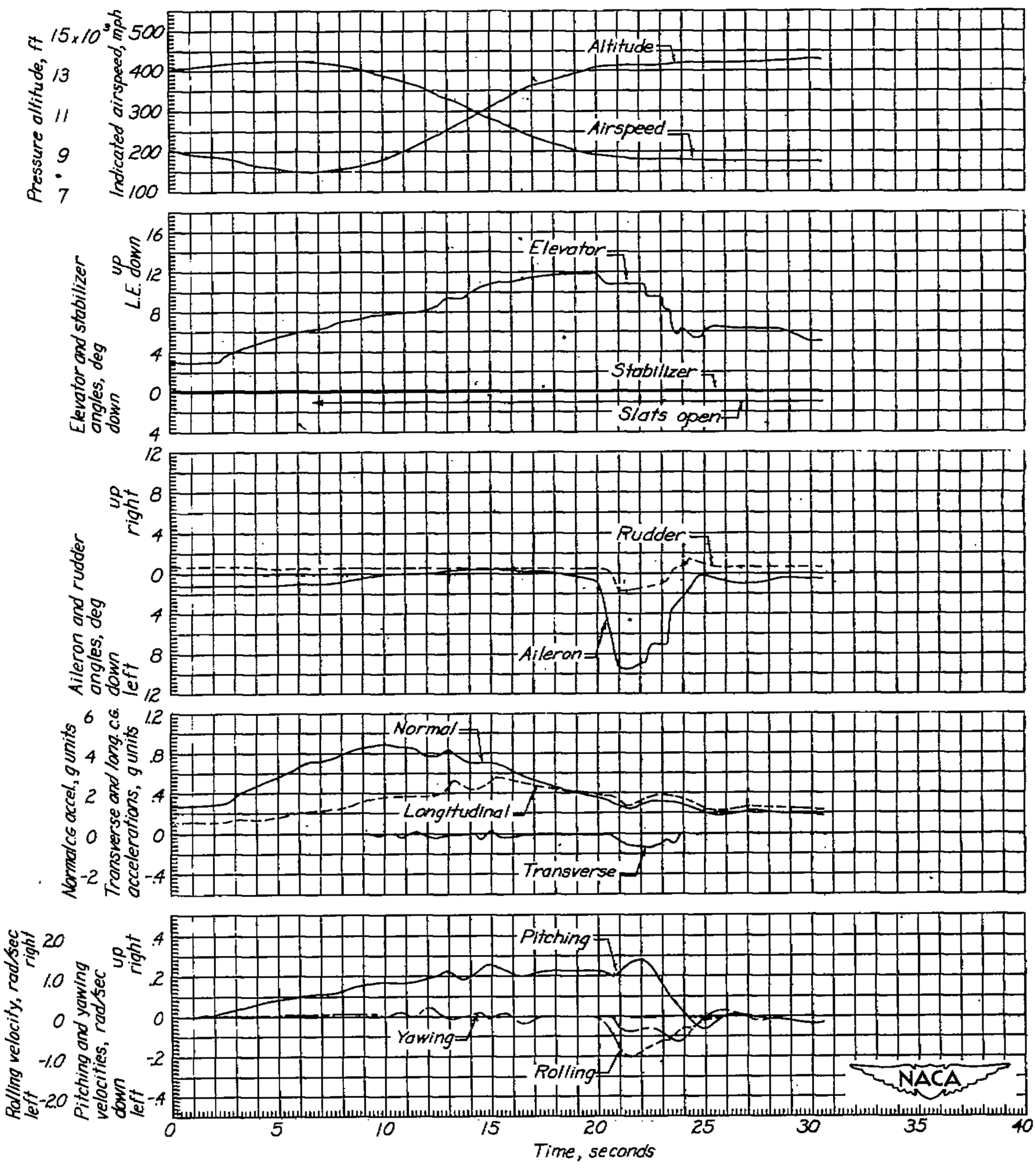

Figure 31.- Immelman turn. Airplane weight, 12,600 pounds; center of gravity at 23.2-percent mean aerodynamic chord.

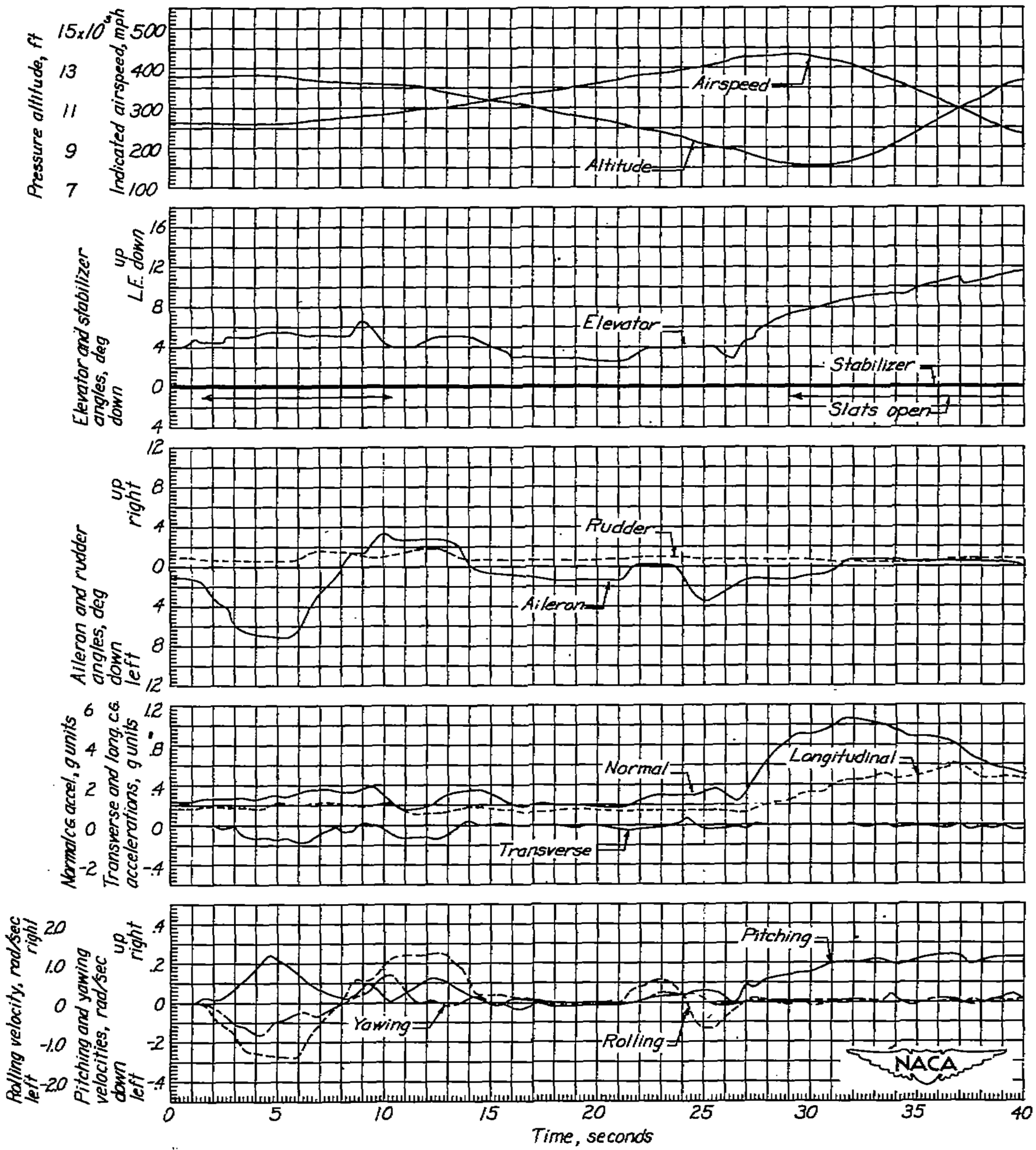

Figure 32.- Slow rolls followed by a dive and pull-up into an Immelman turn. Airplane weight, 12,500 pounds; center of gravity at 23.3-percent mean aerodynamic chord.

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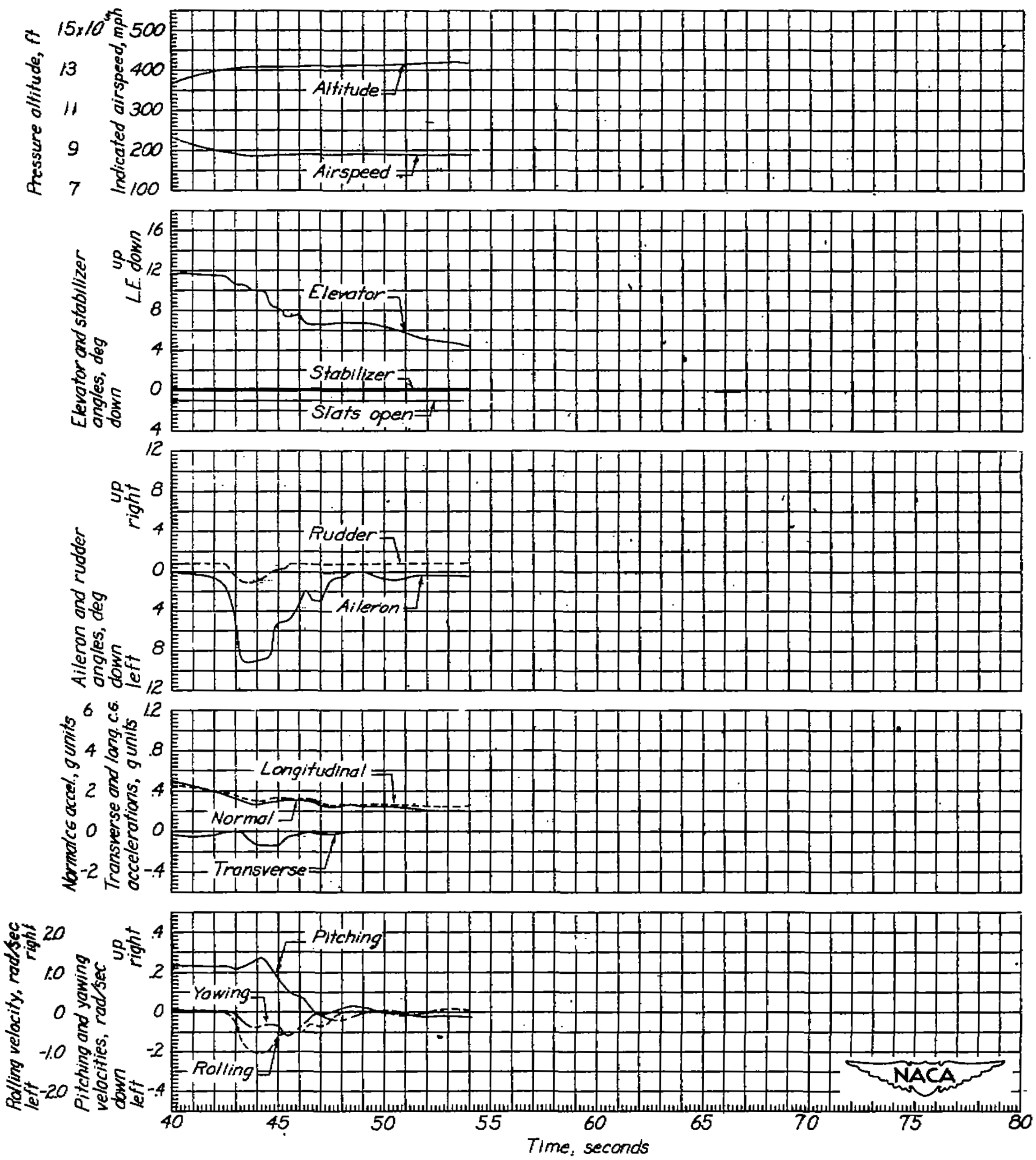

Figure 32.- Concluded.

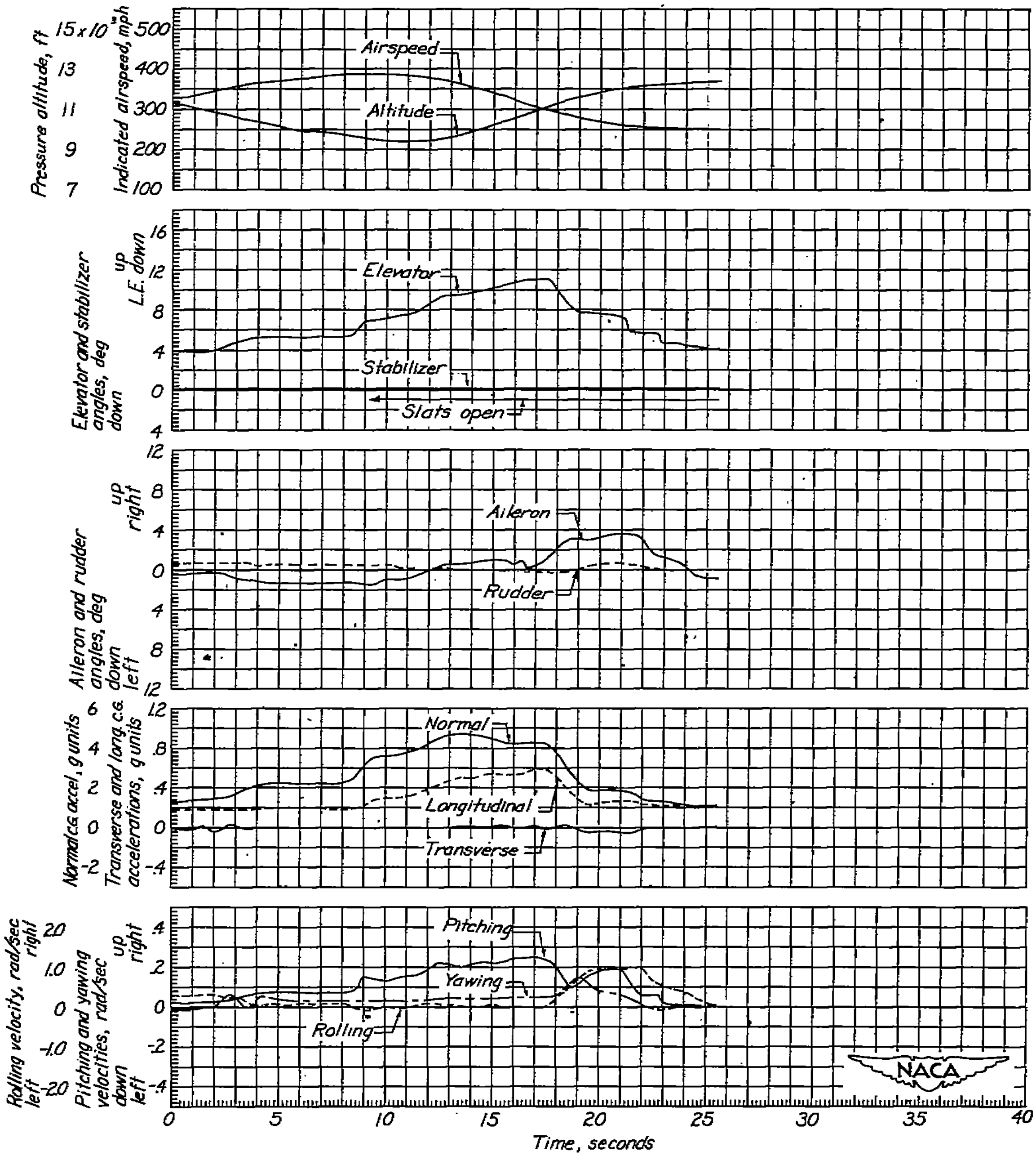

Figure 33.- Diving turn, pull-up, and barrel roll. Airplane weight, 12,500 pounds; center of gravity at 23.3-percent mean aerodynamic chord.

[redacted]

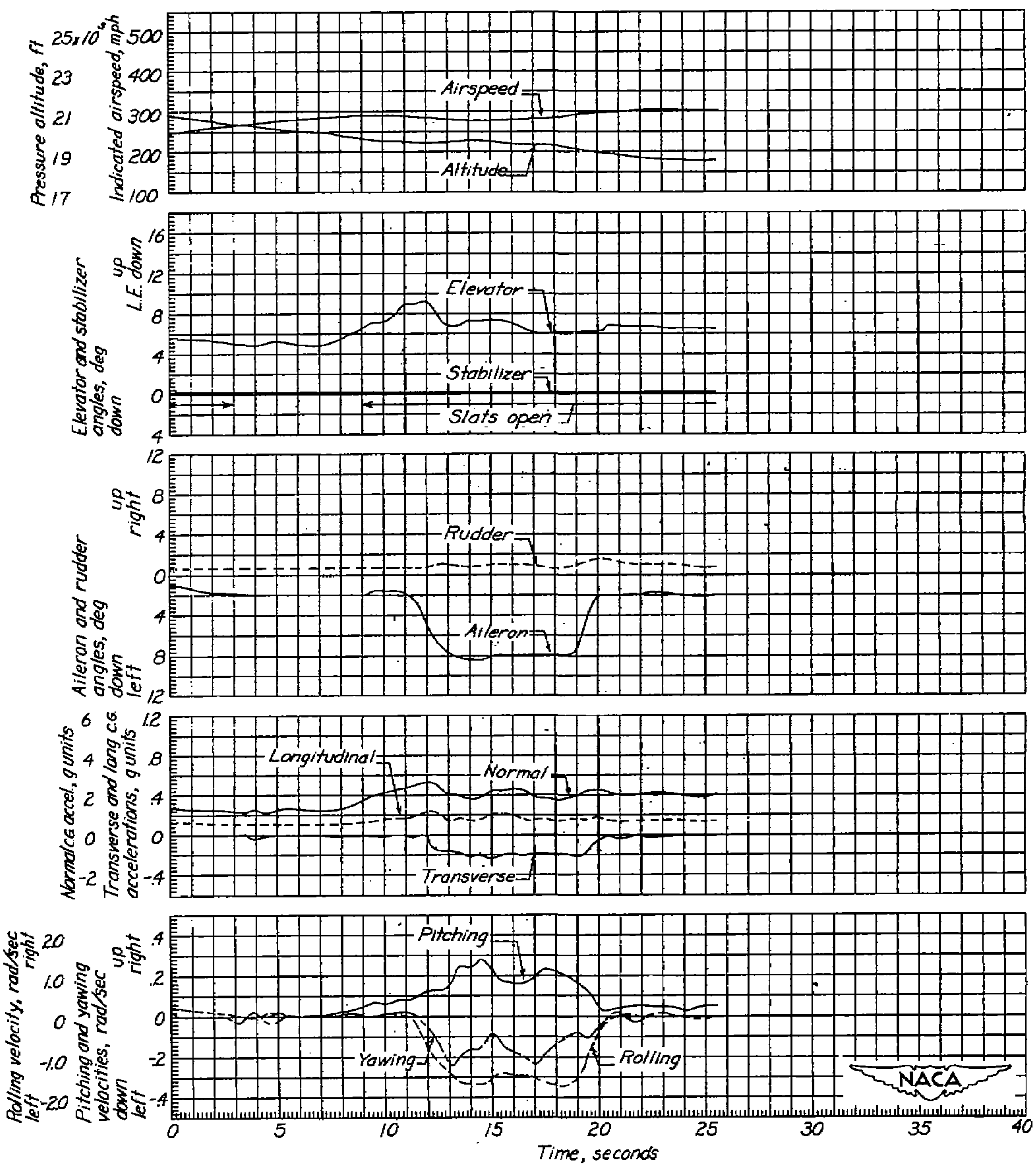

Figure 34.- Barrel rolls. Airplane weight, 12,300 pounds; center of gravity at 23.4-percent mean aerodynamic chord.

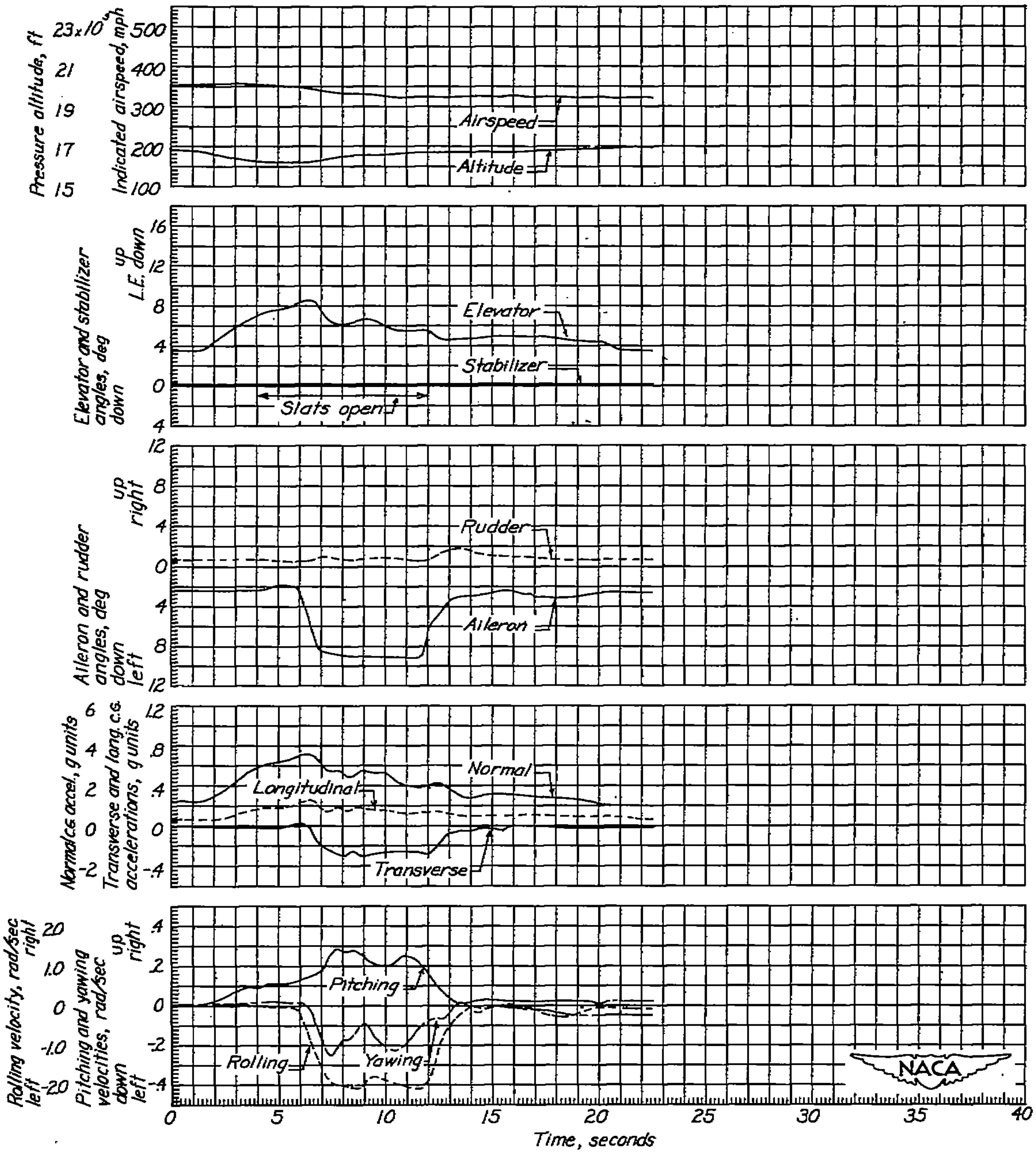

Figure 35.- Barrel rolls. Airplane weight, 12,150 pounds; center of gravity at 23.5-percent mean aerodynamic chord.

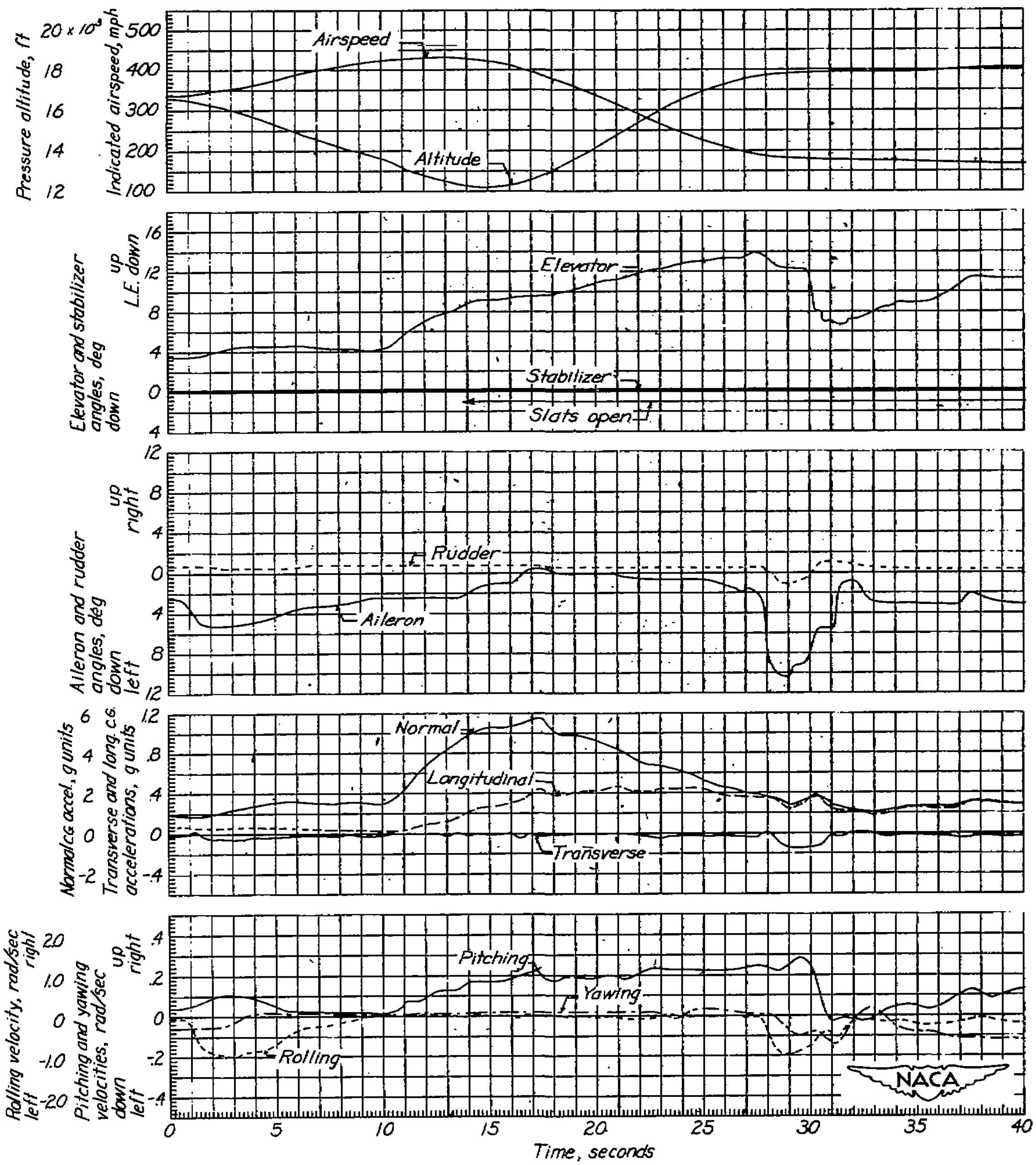

Figure 36.- Roll entry into a dive and pull-up into an Immelman turn. Airplane weight, 12,100 pounds; center of gravity at 23.5-percent mean aerodynamic chord.

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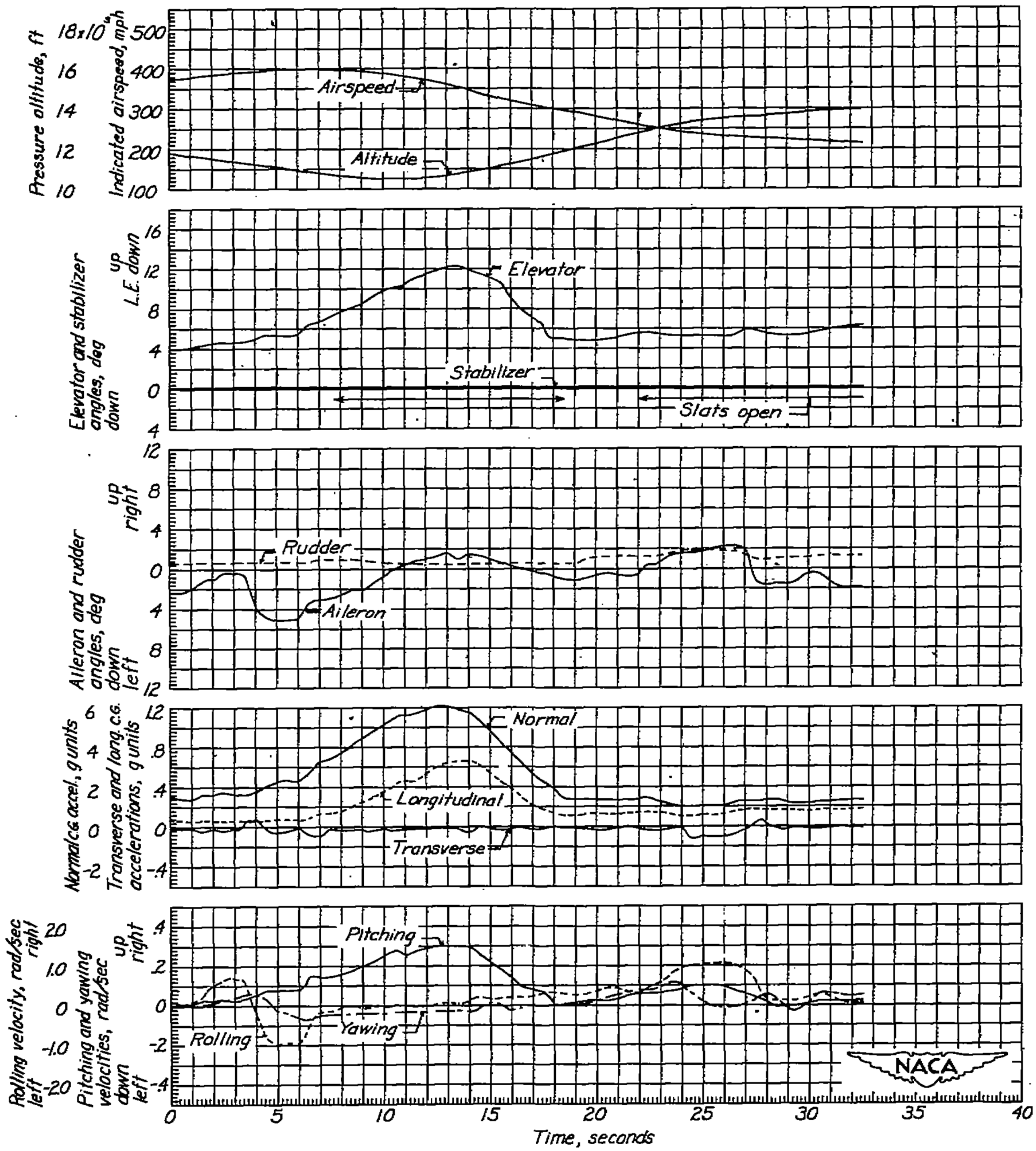


Figure 37.- Quarter-rolls in a dive, pull-up, and barrel roll. Airplane weight, 12,100 pounds; center of gravity at 23.5-percent mean aerodynamic chord.

[redacted]

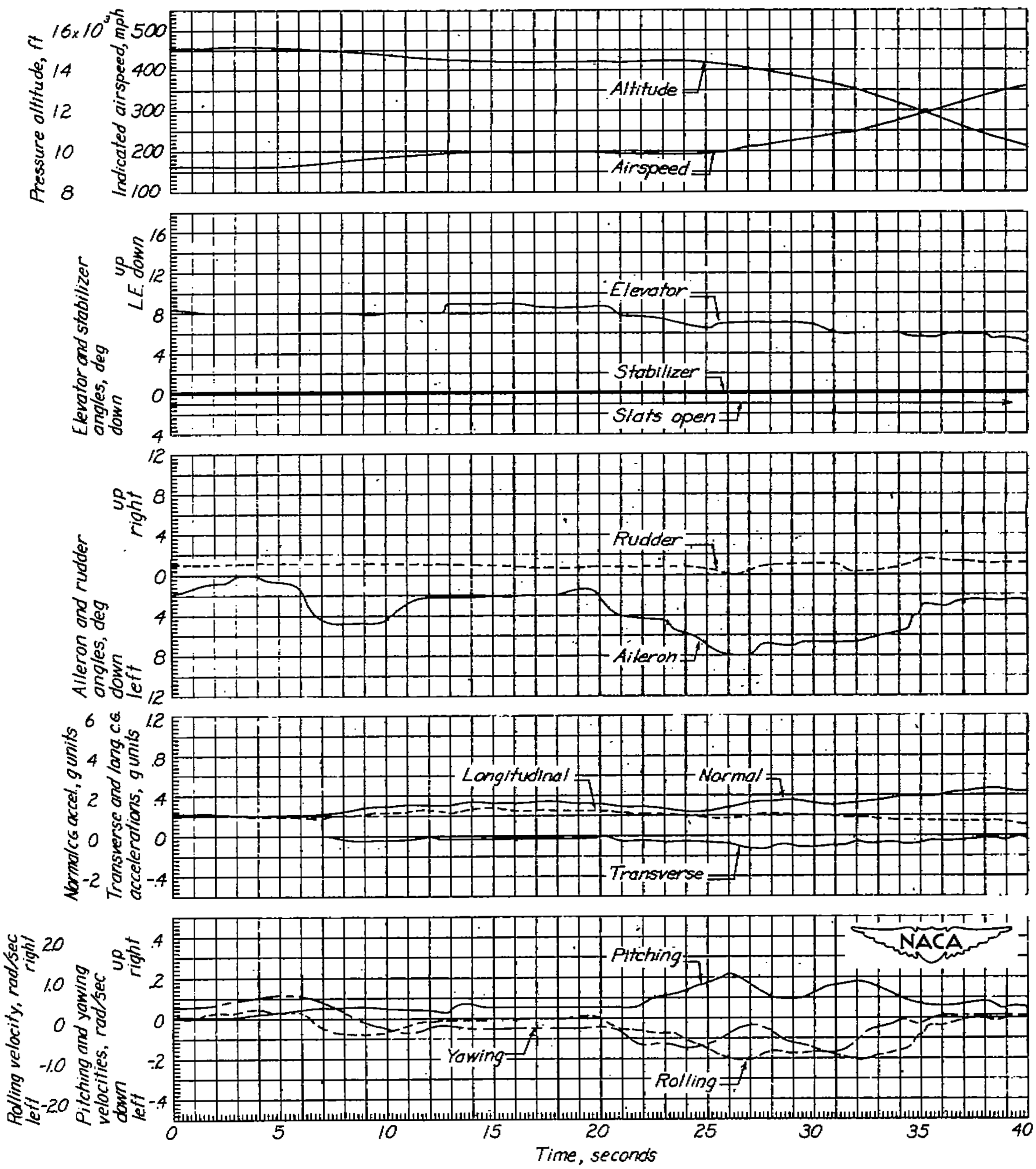
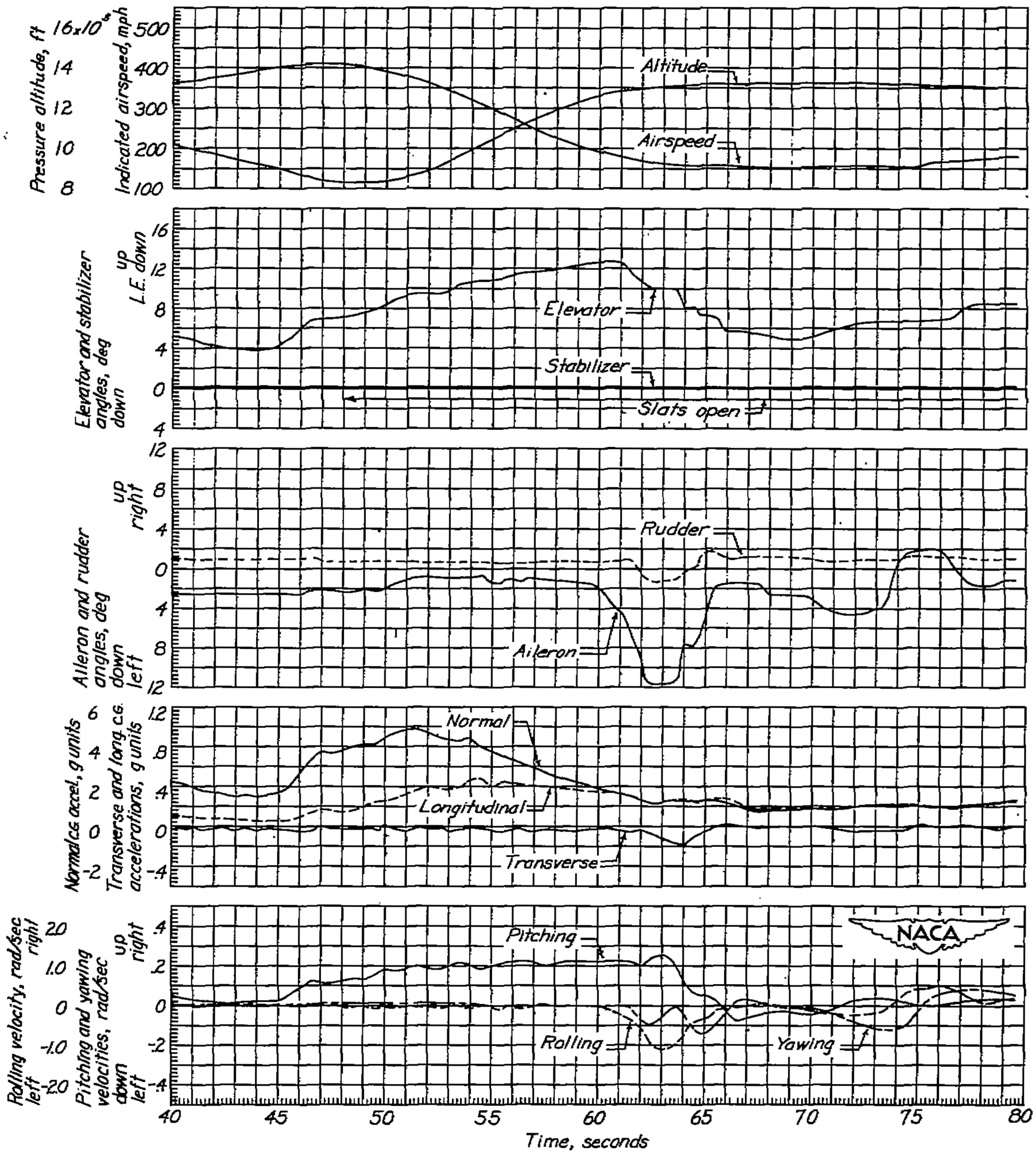


Figure 38.- Low-speed turns, barrel rolls in a dive, and pull-up into an Immelman turn. Airplane weight, 12,050 pounds; center of gravity at 23.5-percent mean aerodynamic chord.



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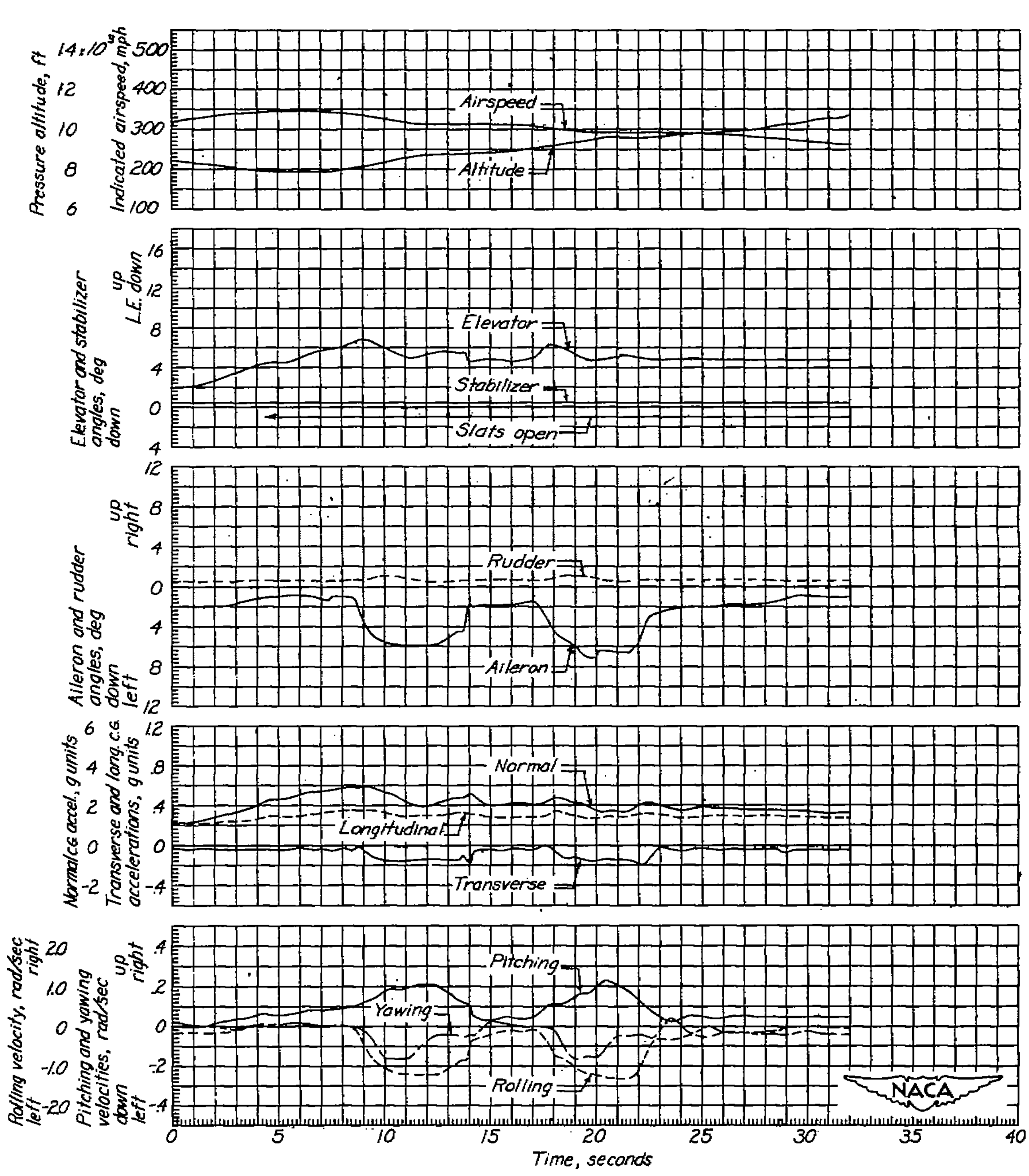


Figure 39.- Barrel rolls. Airplane weight, 13,400 pounds; center of gravity at 22.9-percent mean aerodynamic chord.

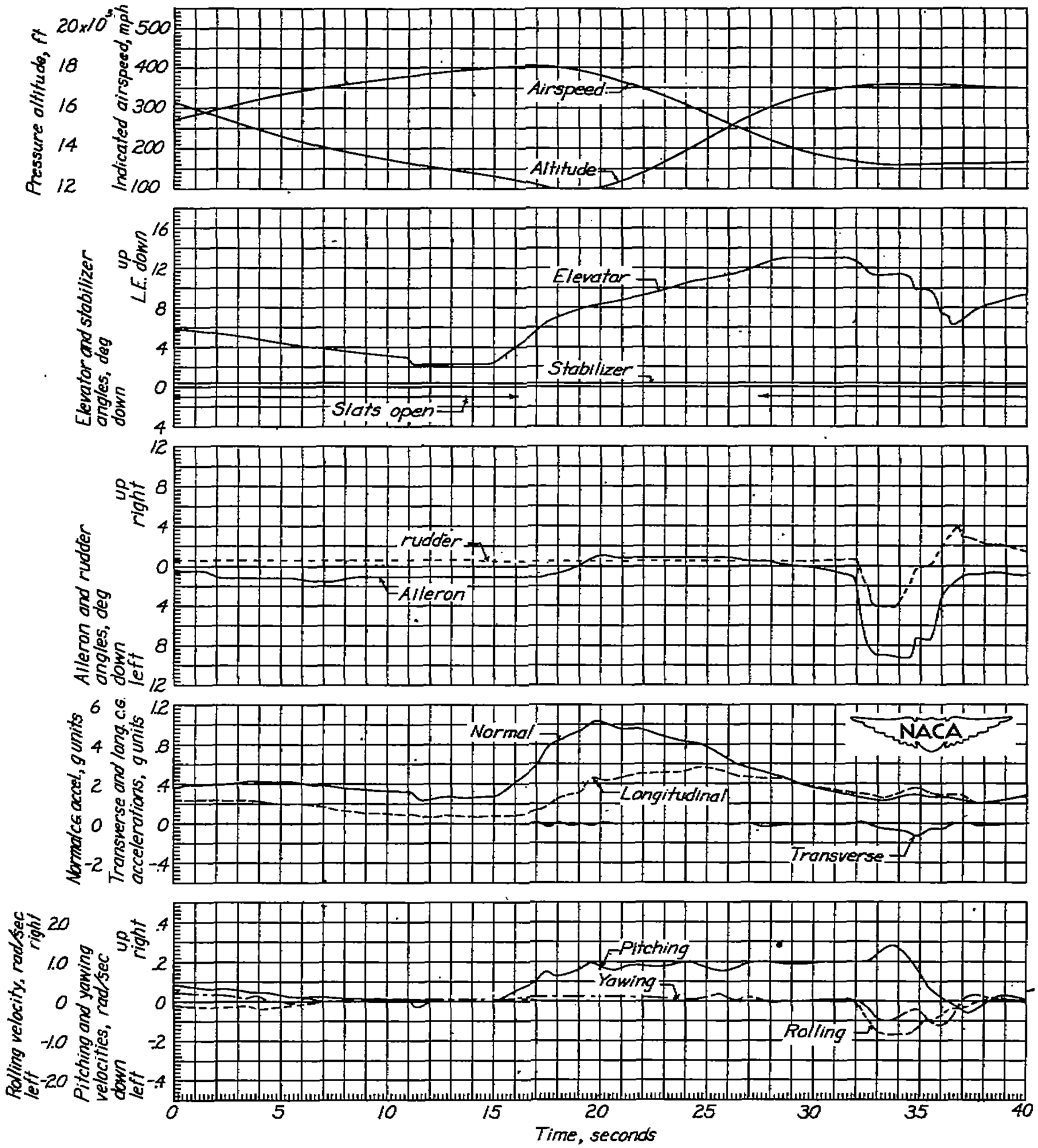


Figure 40.- Dive and pull-up into an Immelman turn. Airplane weight, 13,300 pounds; center of gravity at 22.9-percent mean aerodynamic chord.

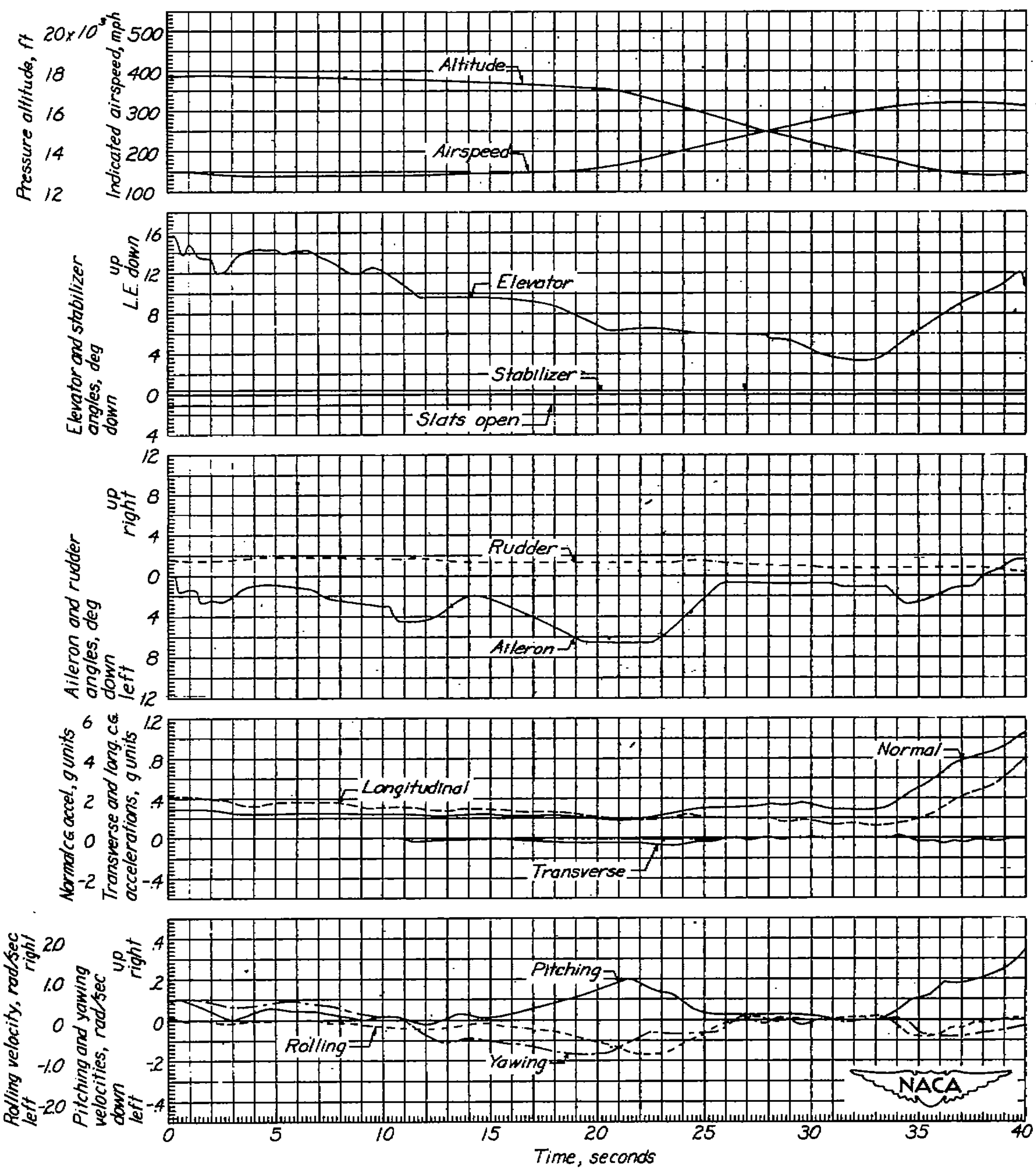
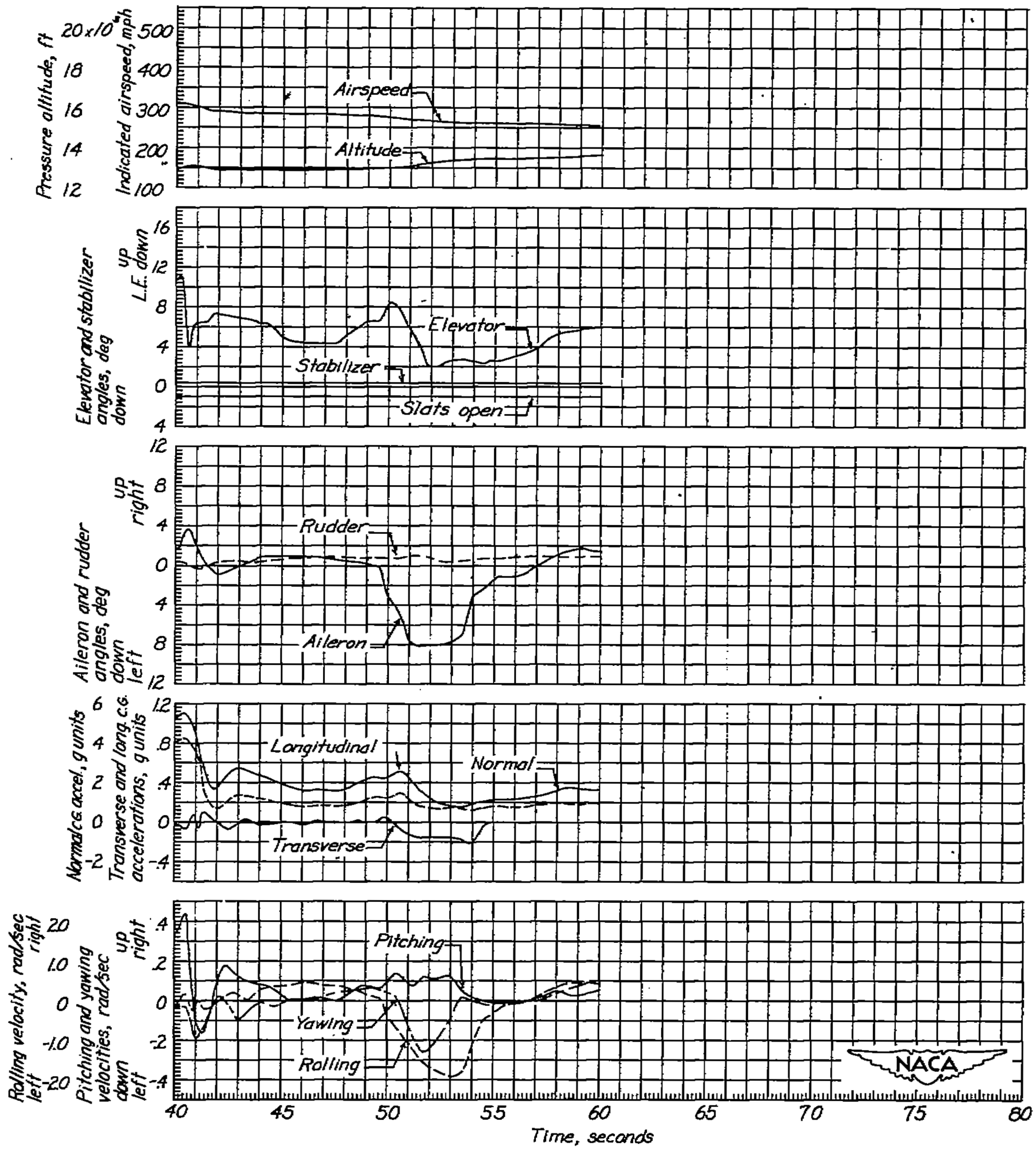


Figure 41.- Roll entry into a dive, pull-out, and barrel roll. Airplane weight, 13,200 pounds; center of gravity at 23.0-percent mean aerodynamic chord.



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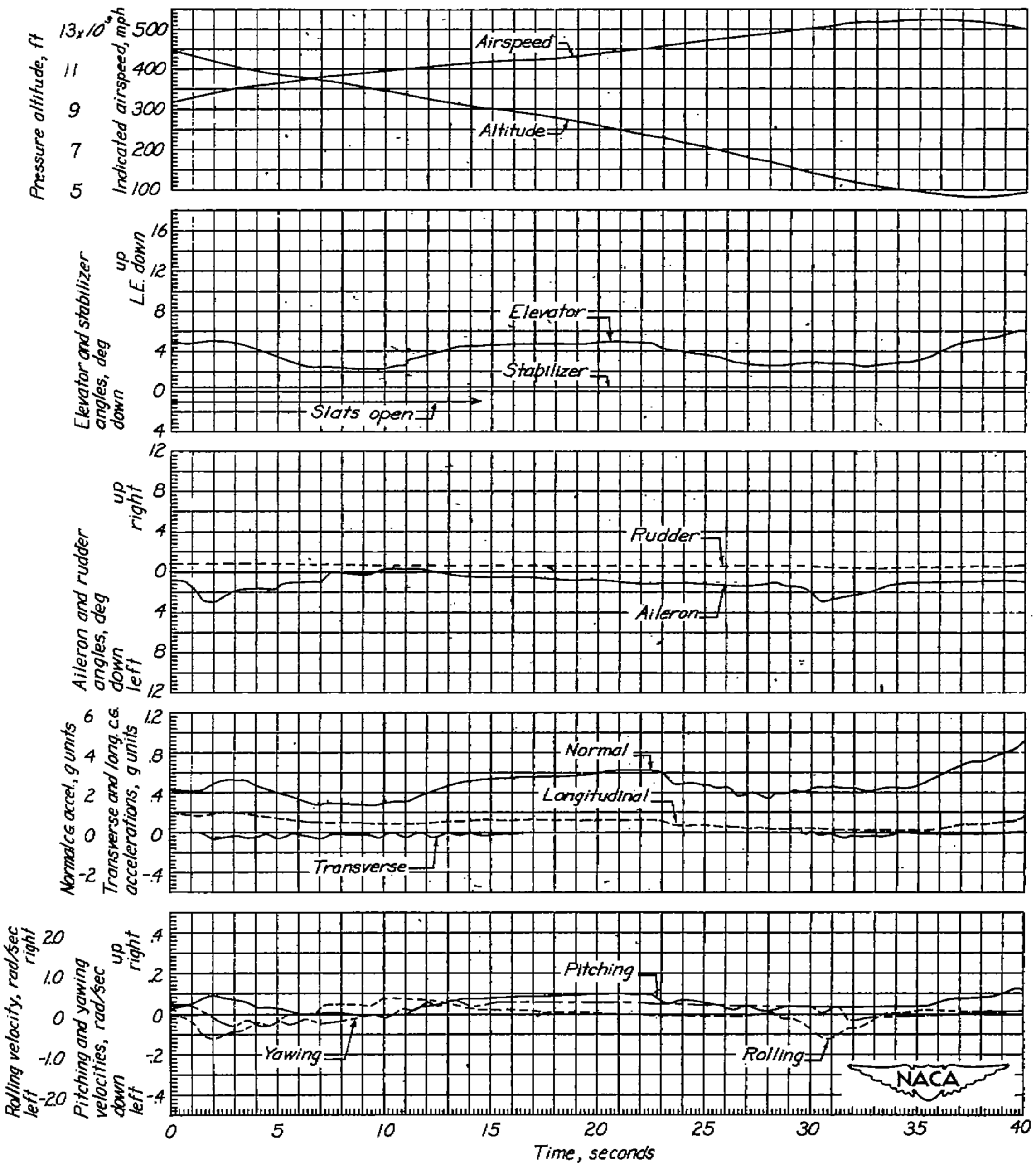
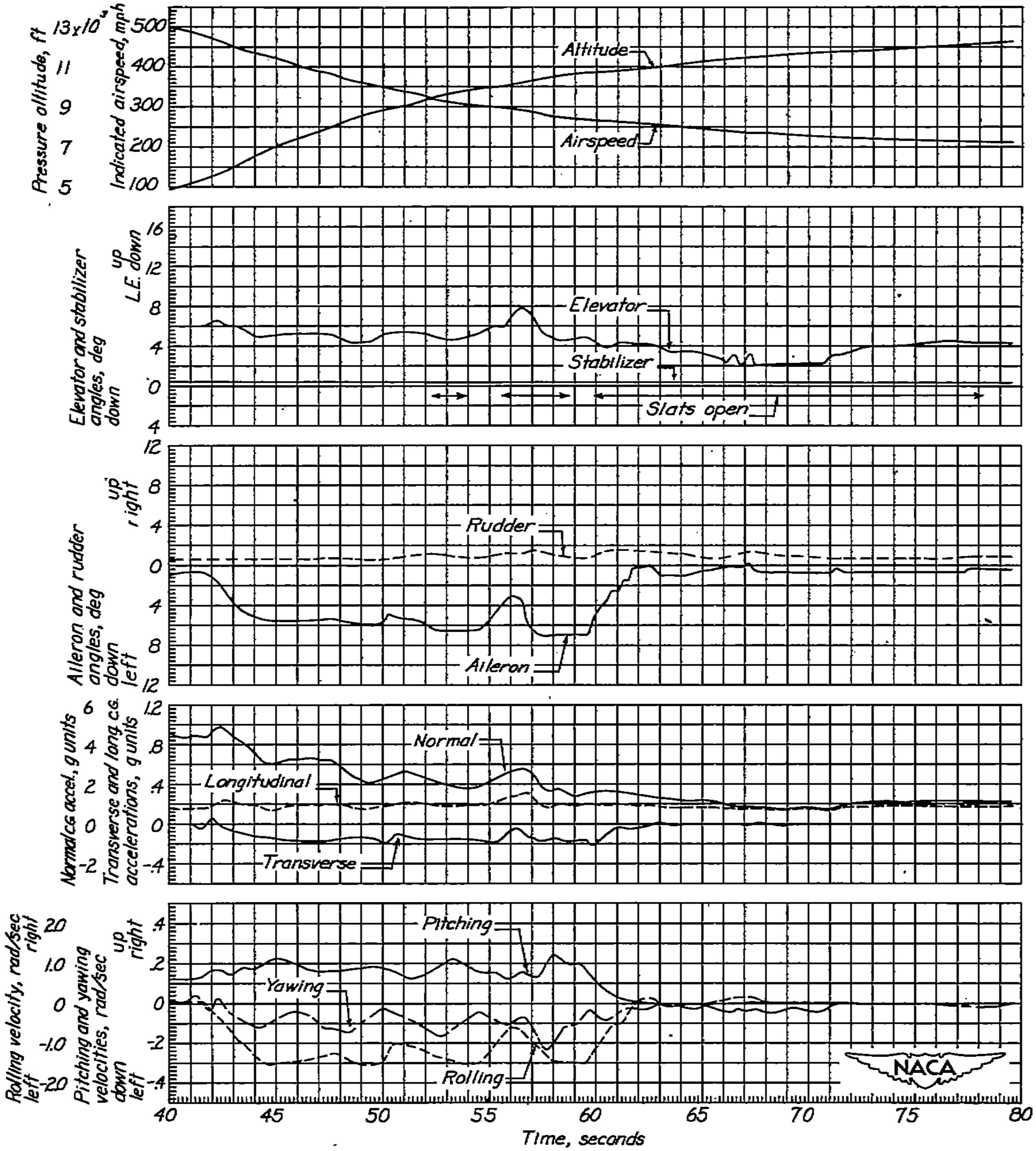


Figure 42.- Diving turns, pull-out, and barrel rolls. Airplane weight, 13,150 pounds; center of gravity at 23.0-percent mean aerodynamic chord.



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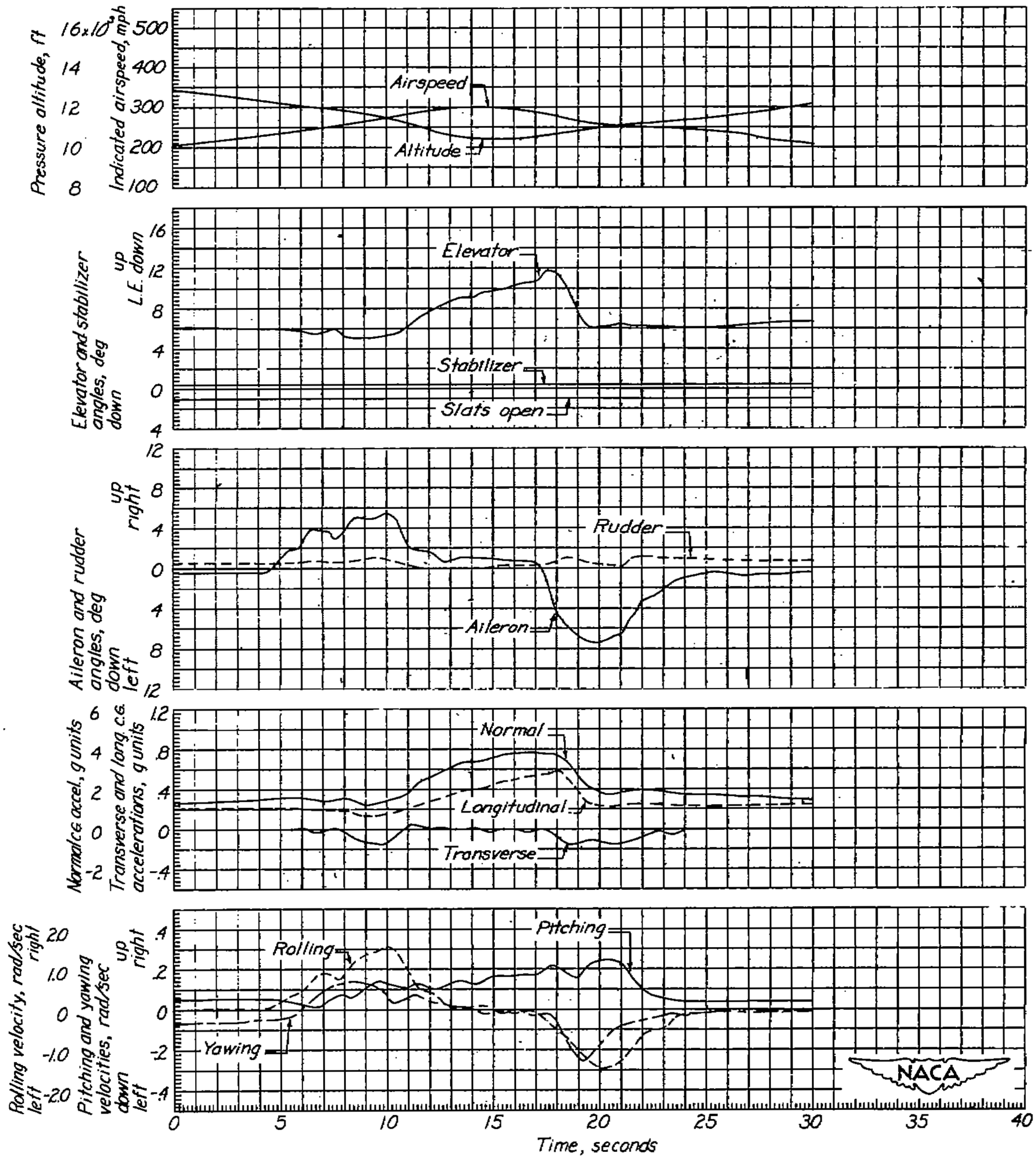


Figure 43.- Barrel roll in a dive and pull-out followed by a barrel roll. Airplane weight, 13,100 pounds; center of gravity at 23.1-percent mean aerodynamic chord.

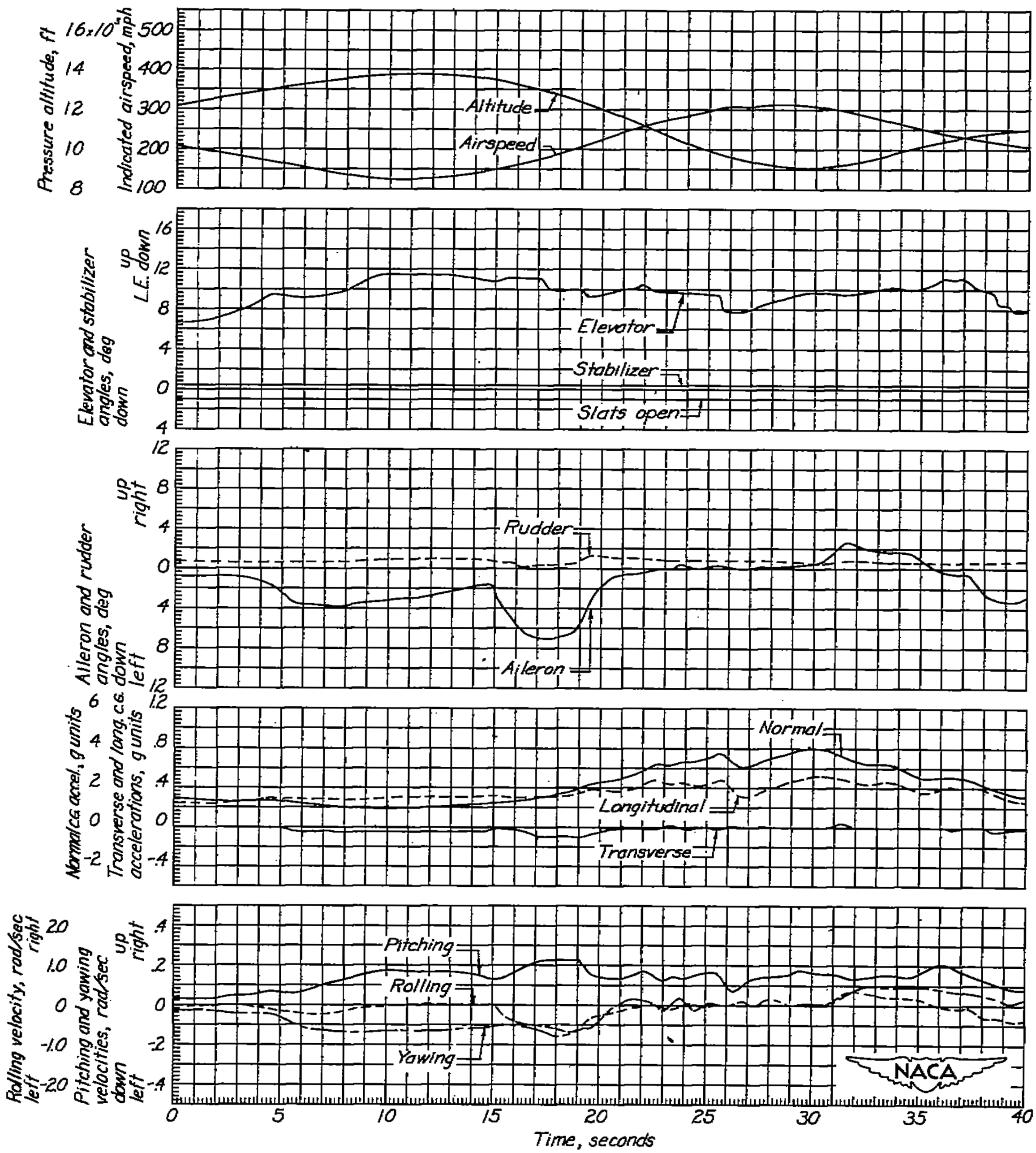
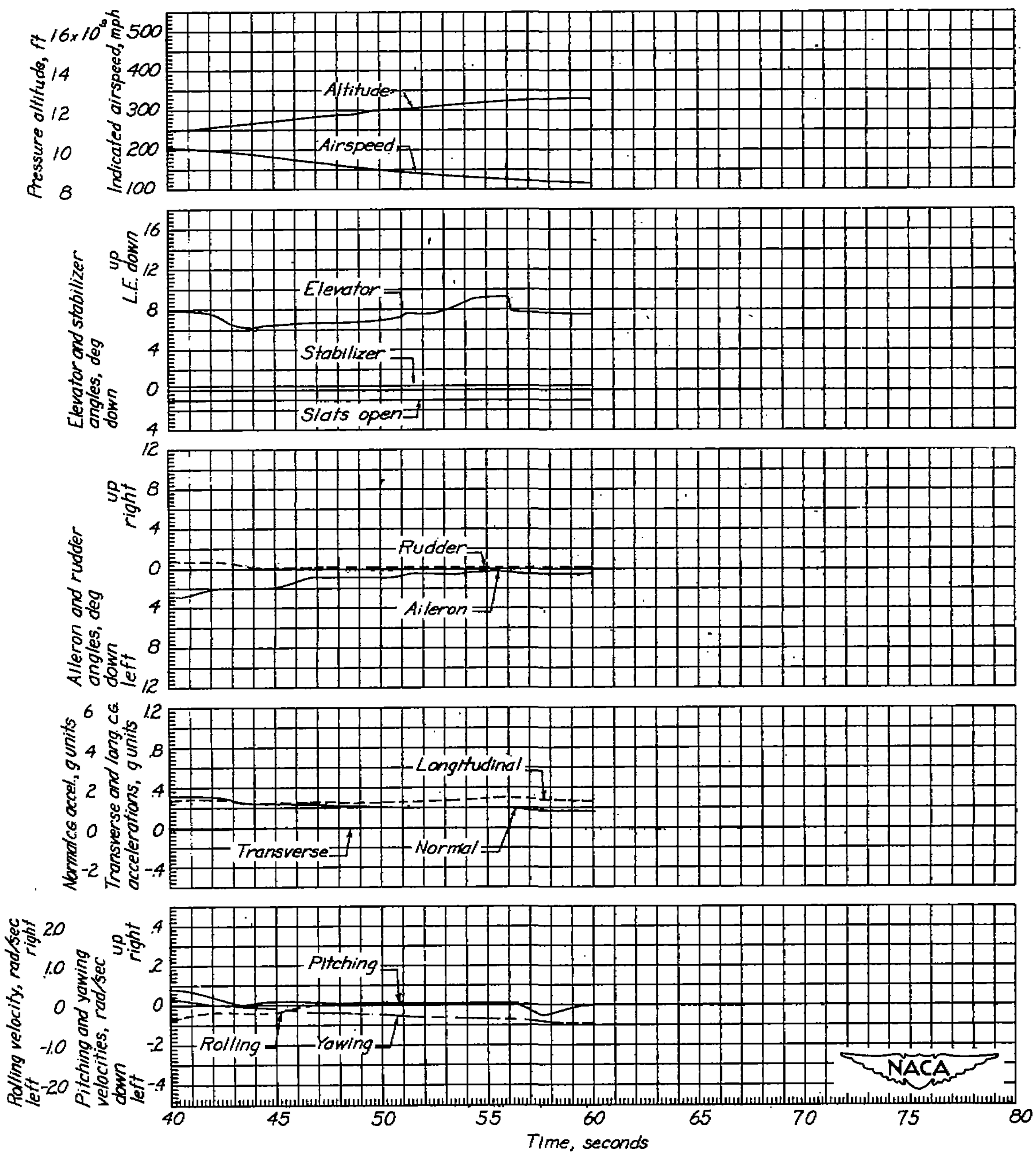


Figure 44.- Turn entry into a split S followed by climbing turns. Airplane weight, 13,050 pounds; center of gravity at 23.1-percent mean aerodynamic chord.



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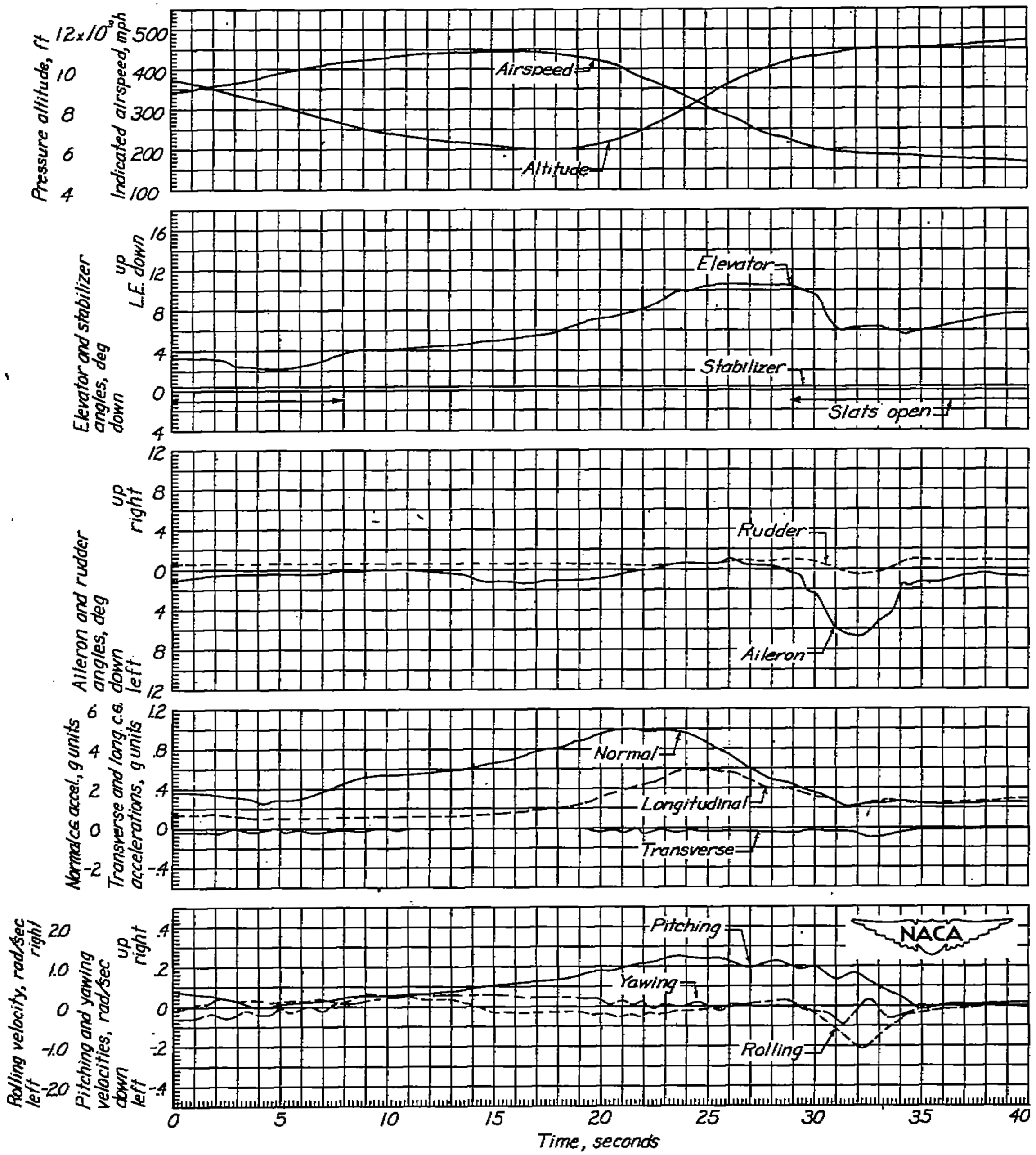
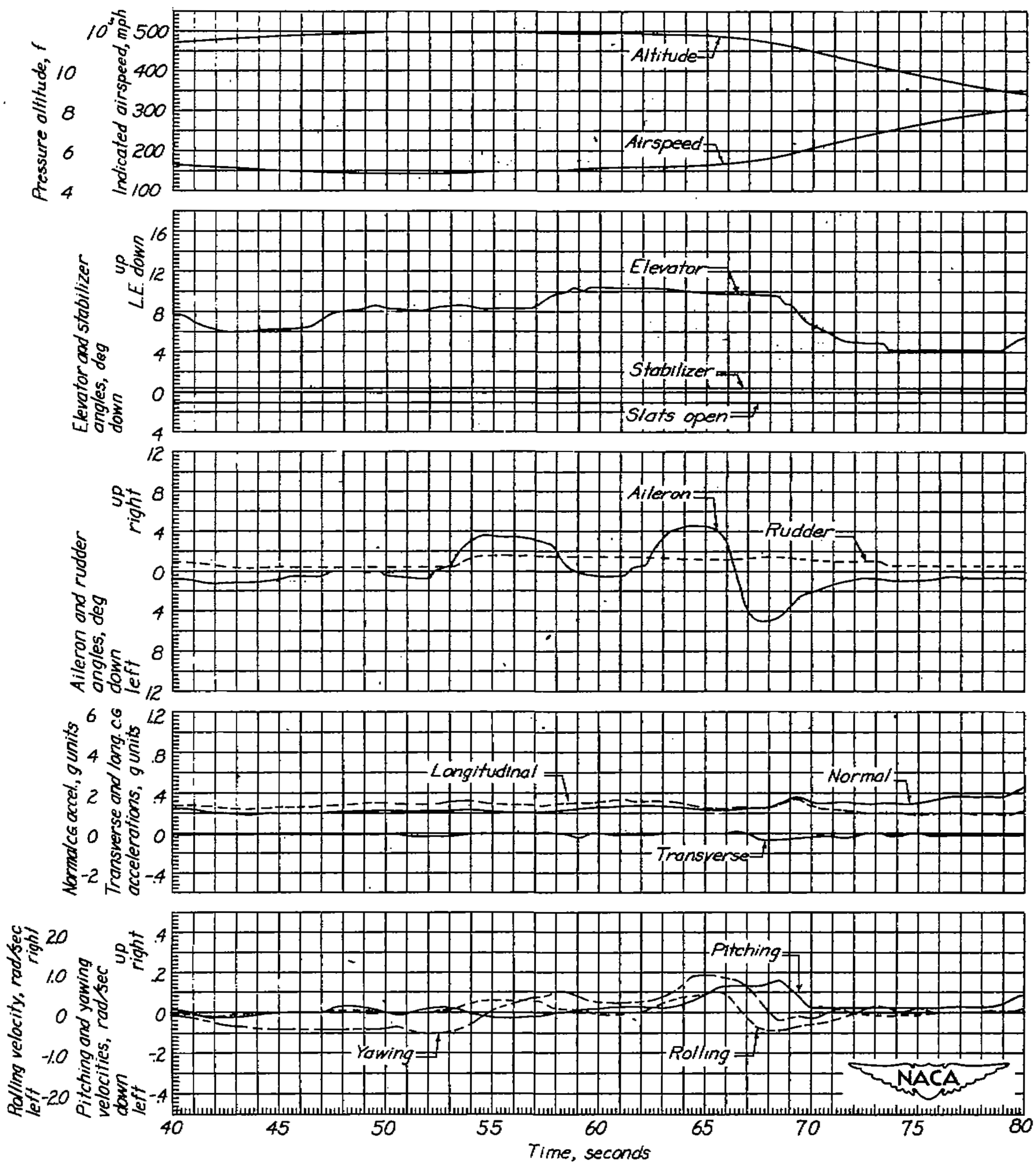


Figure 45.- Diving turn and pull-up into an Immelman turn followed by turns and quarter-rolls. Airplane weight, 12,900 pounds; center of gravity at 23.1-percent mean aerodynamic chord.



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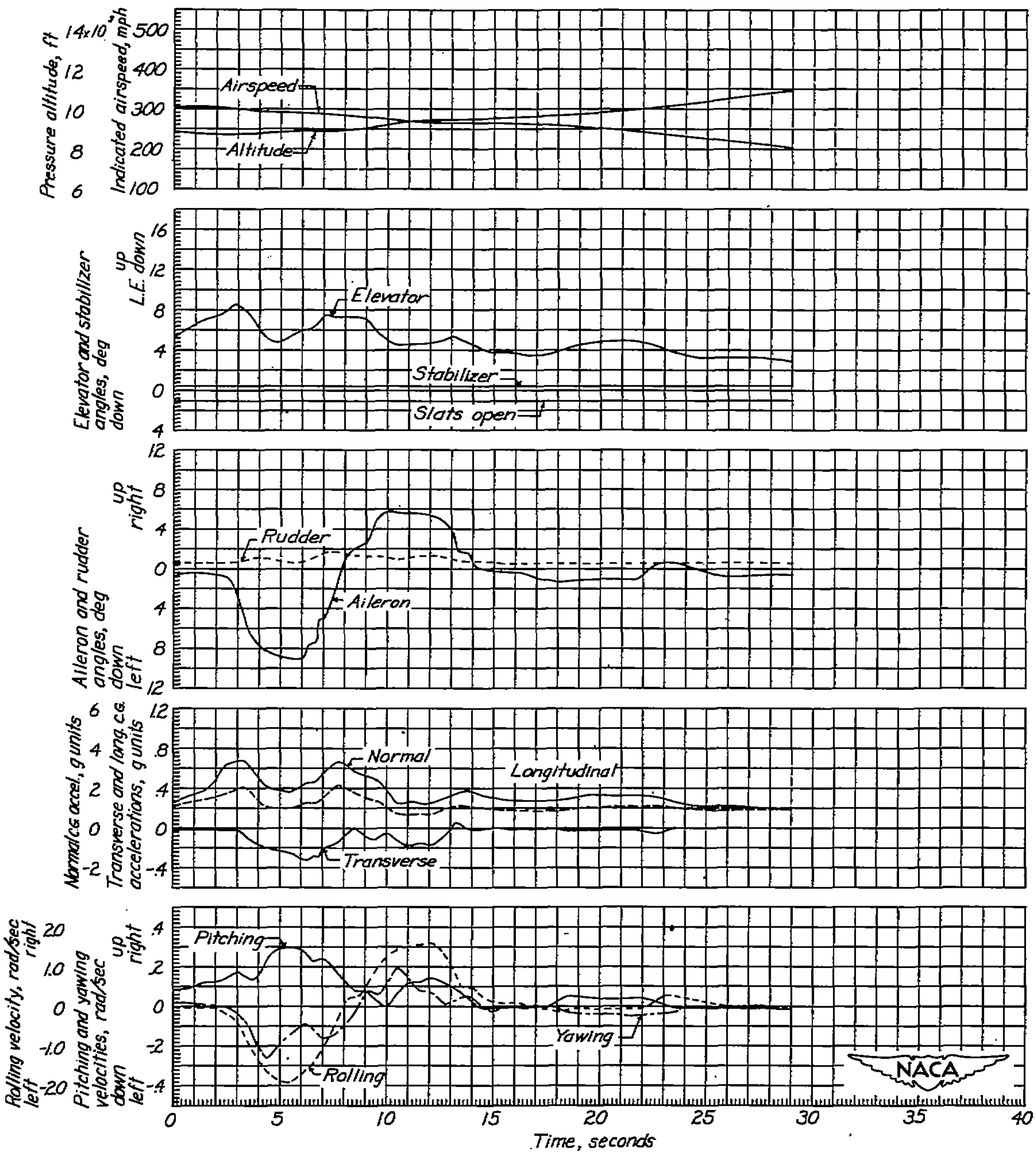


Figure 46.- Barrel rolls. Airplane weight, 12,850 pounds; center of gravity at 23.2-percent mean aerodynamic chord.

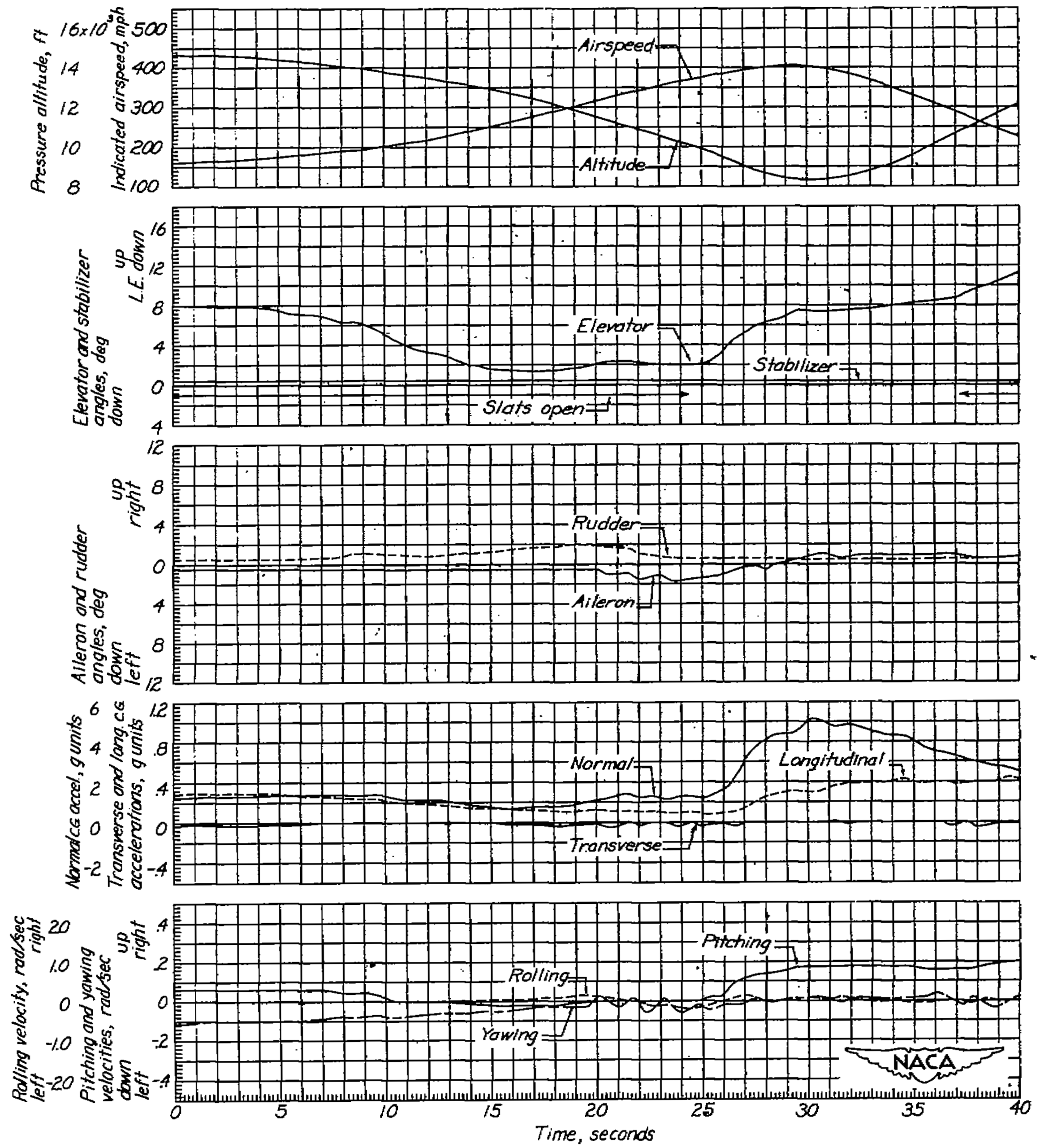
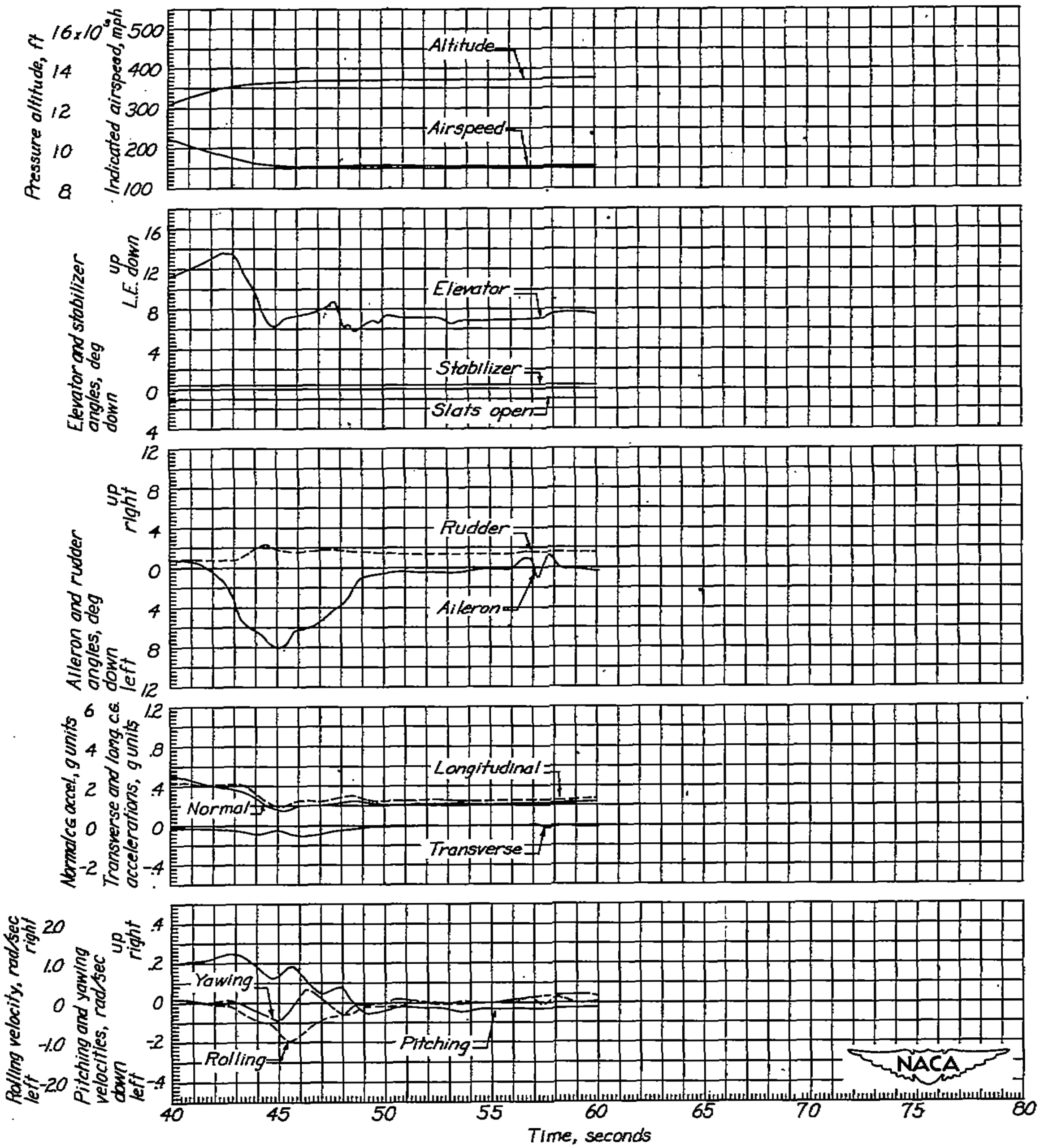


Figure 47.- Diving turn and pull-up into an Immelman turn. Airplane weight, 12,650 pounds; center of gravity at 23.2-percent mean aerodynamic chord.



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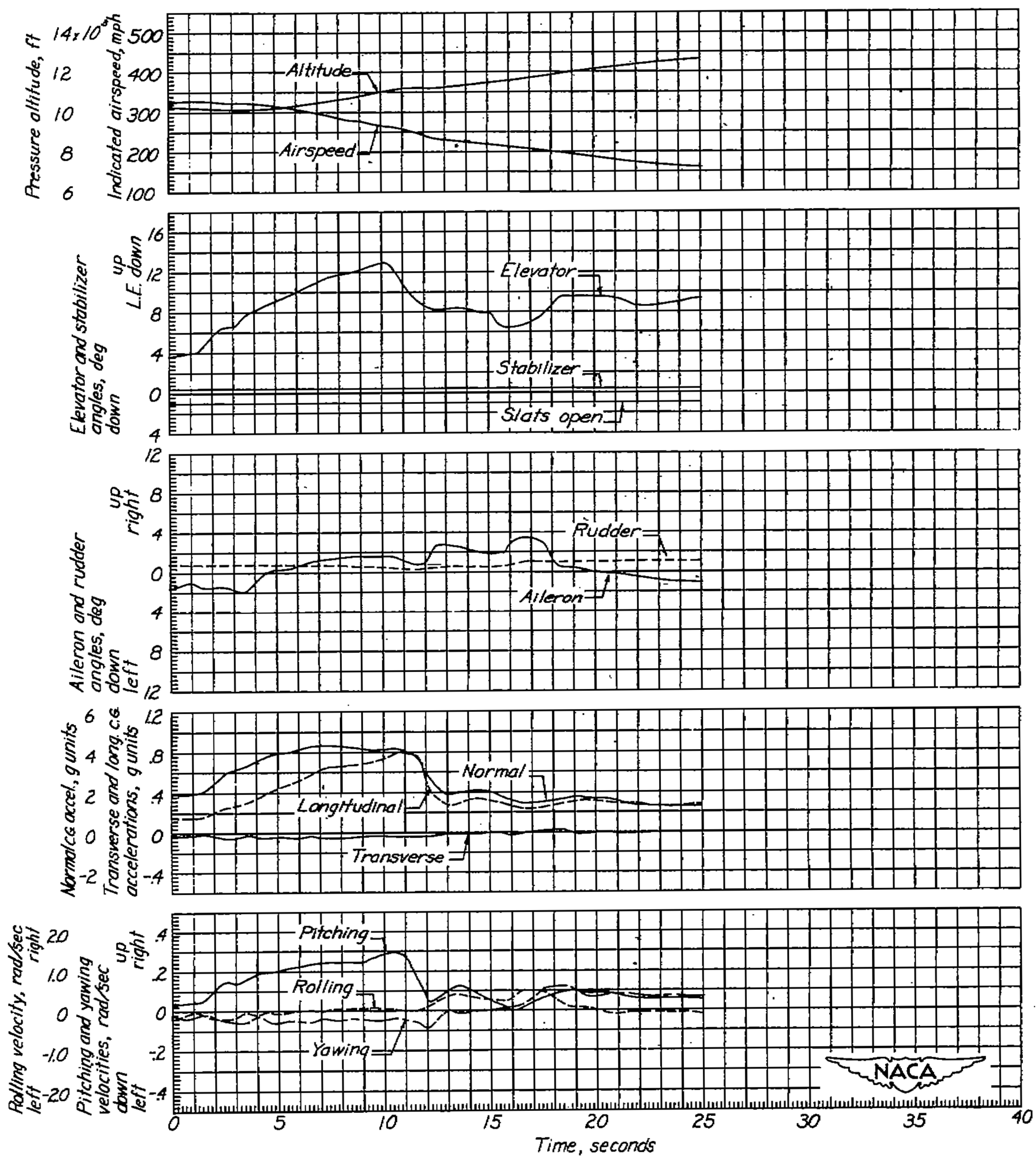

Figure 48.- Chandelle. Airplane weight, 12,600 pounds; center of gravity at 23.3-percent mean aerodynamic chord.

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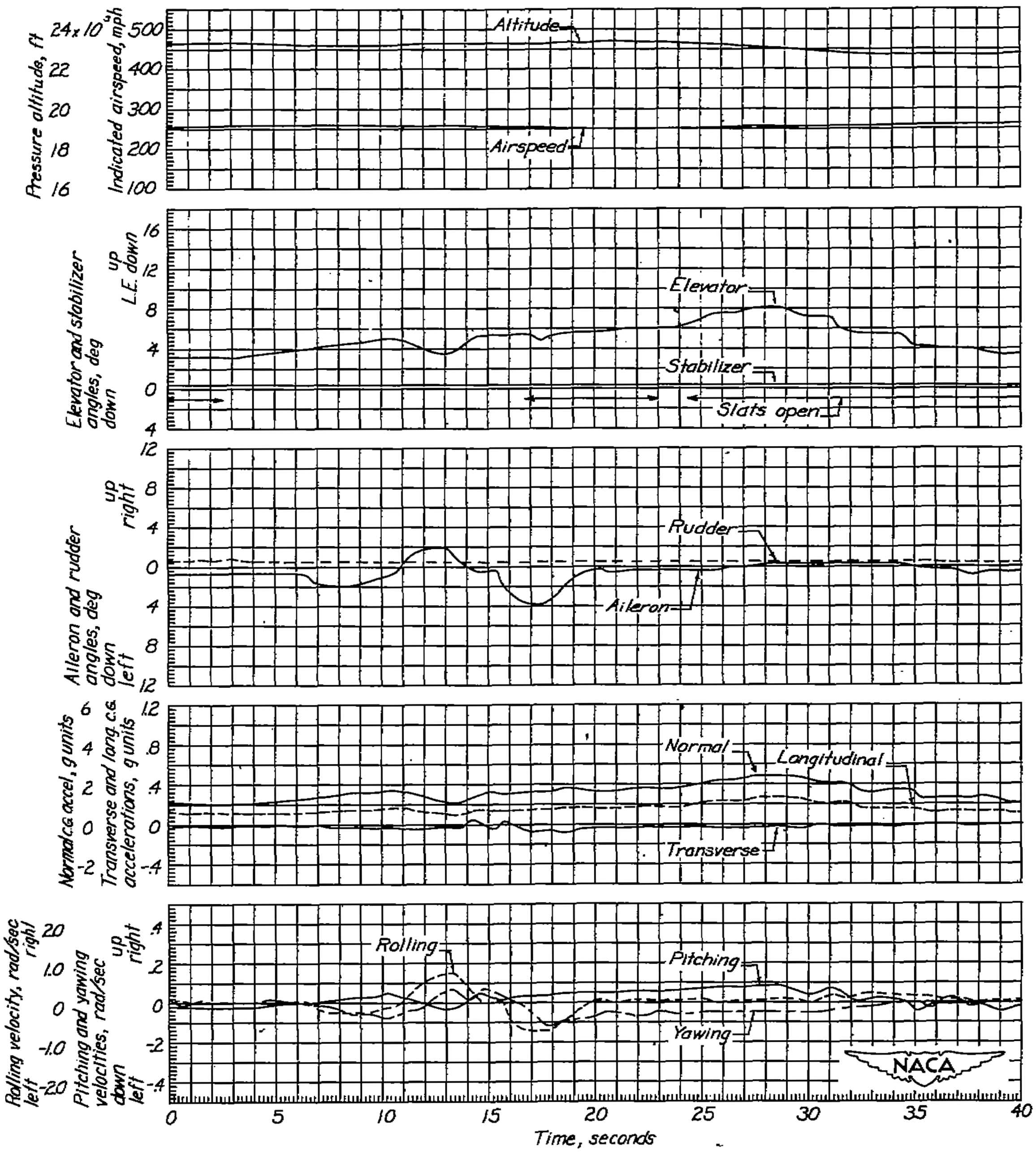

Figure 49.- Gentle turns. Airplane weight, 12,350 pounds; center of gravity at 23.4-percent mean aerodynamic chord.

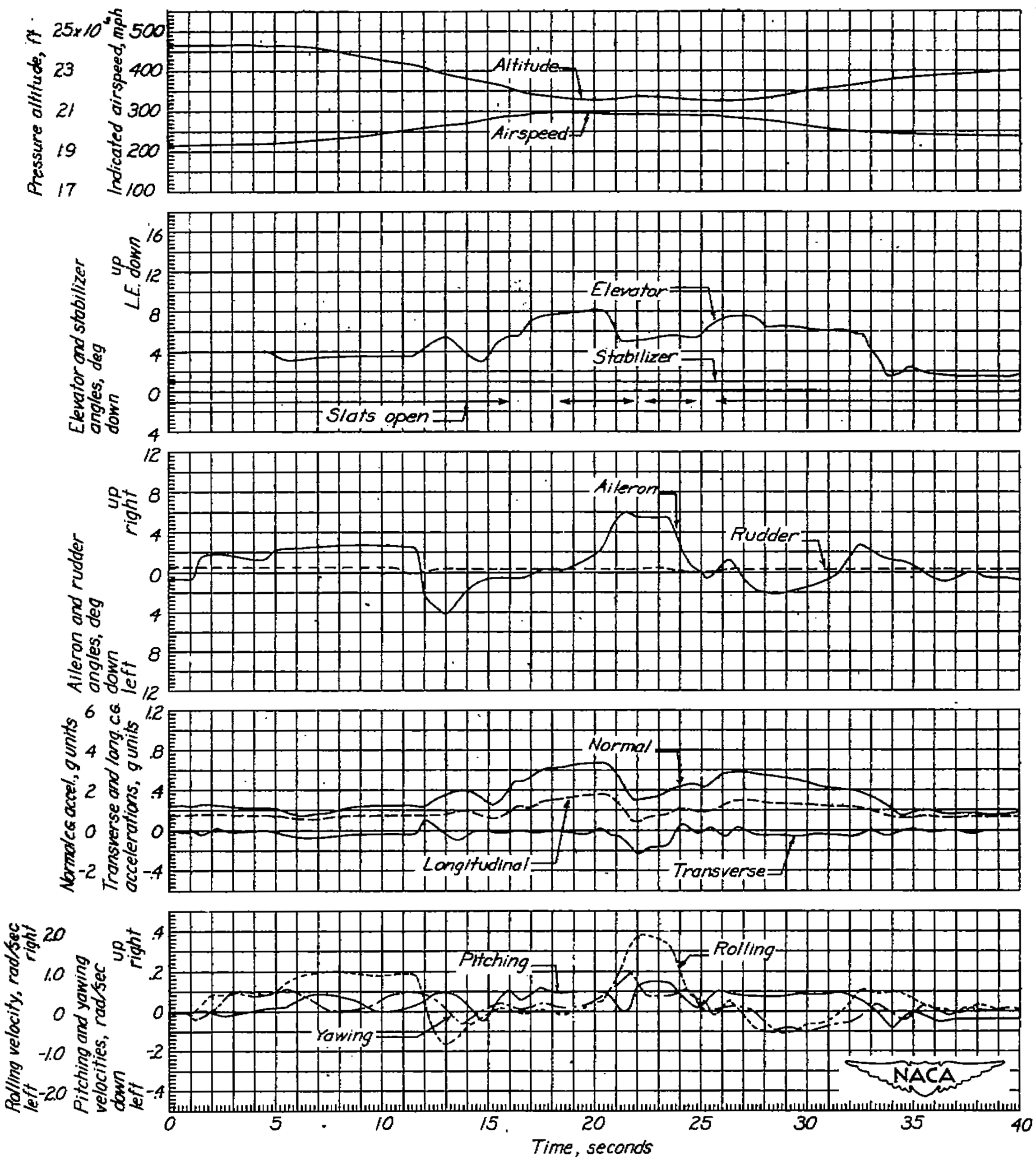

Figure 50.- Roll entry into a dive, pull-out, and barrel roll followed by quarter-rolls. Airplane weight, 12,150 pounds; center of gravity at 23.5-percent mean aerodynamic chord.

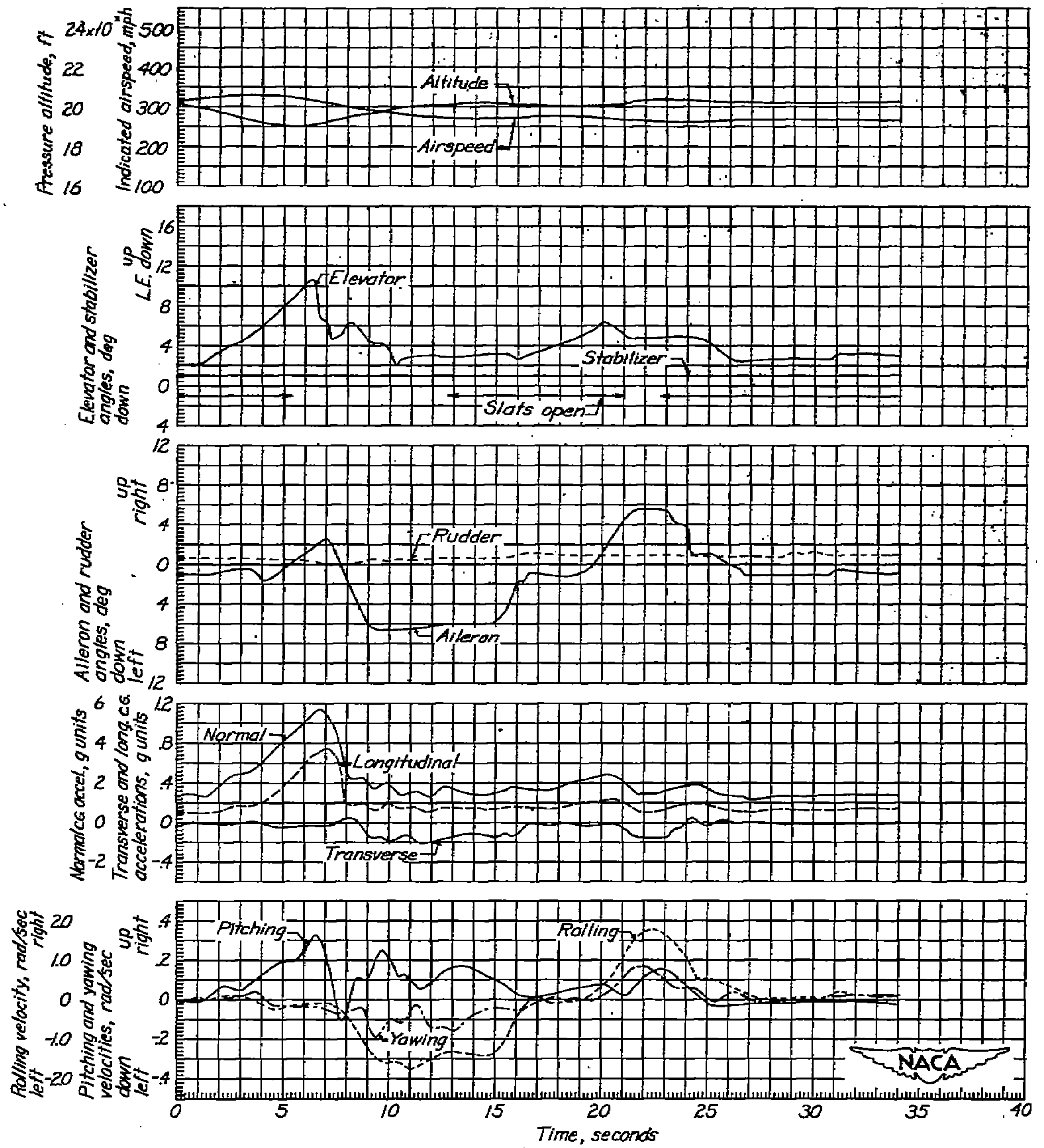

Figure 51.- Dive and pull-out followed by barrel rolls. Airplane weight, 12,050 pounds; center of gravity at 23.5-percent mean aerodynamic chord.

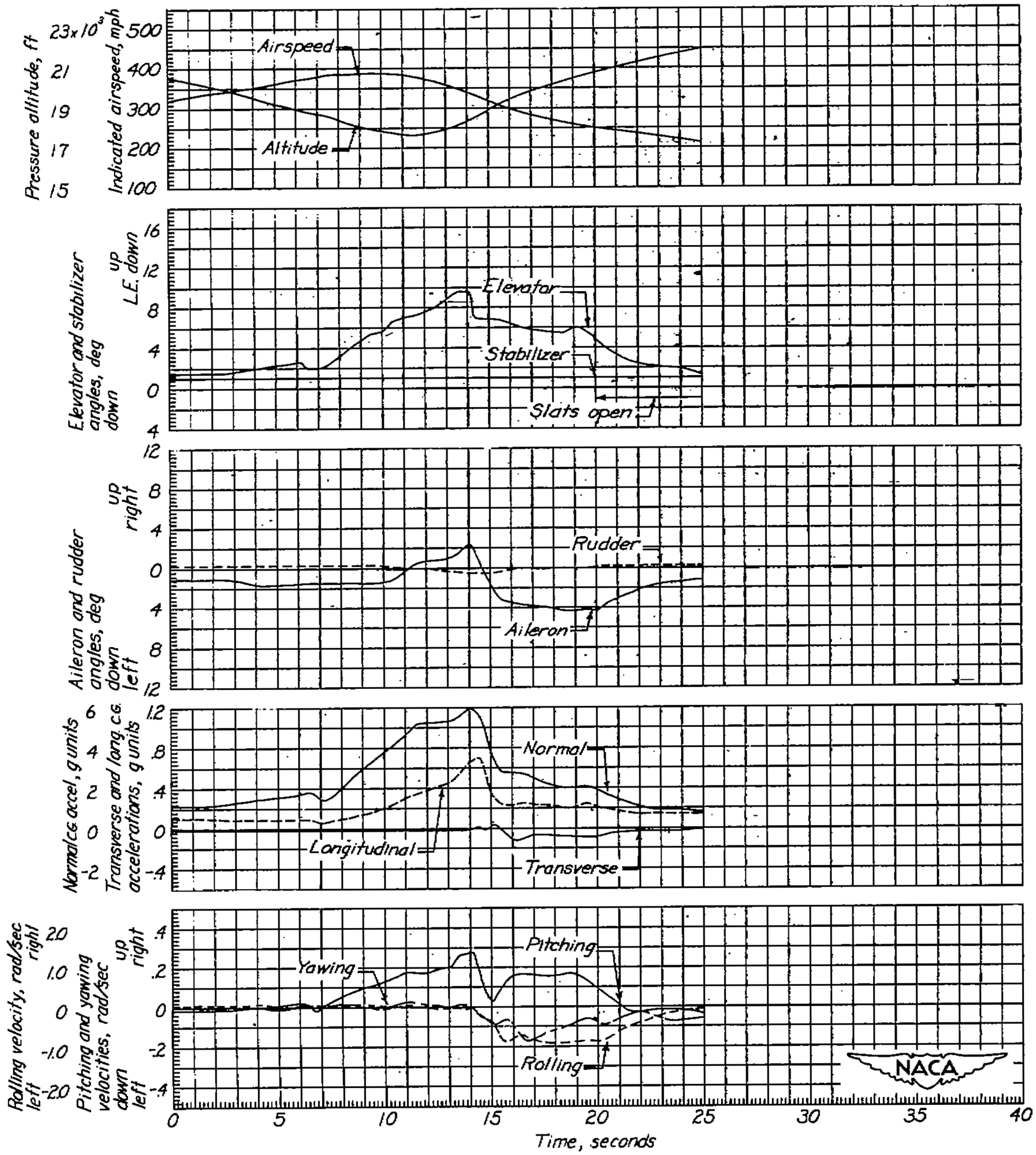

Figure 52.- Dive and pull-out followed by a barrel roll. Airplane weight, 11,900 pounds; center of gravity at 23.6-percent mean aerodynamic chord.

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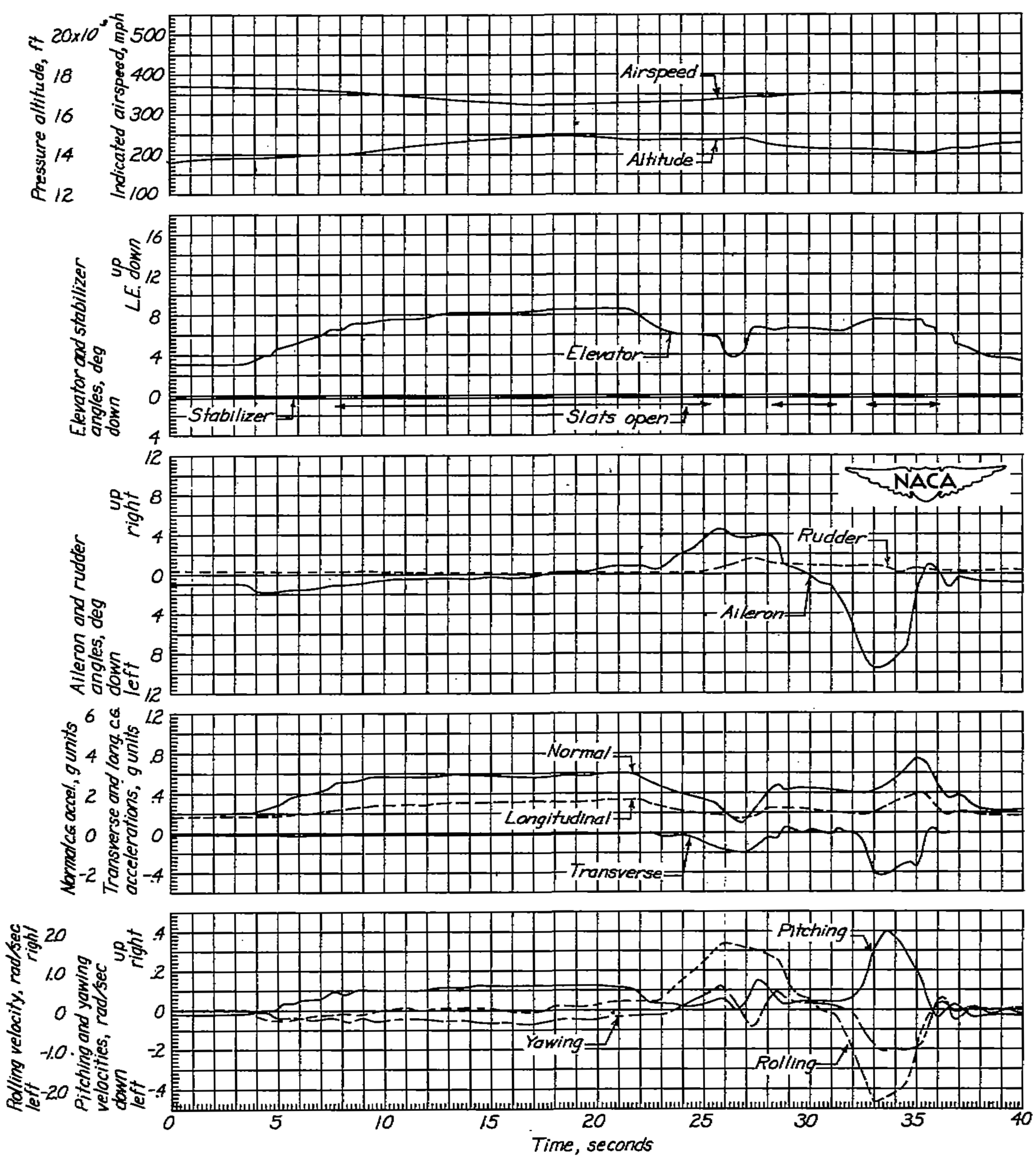

Figure 53.- Sharp climbing turn followed by barrel rolls. Airplane weight, 13,250 pounds; center of gravity at 23.0-percent mean aerodynamic chord.

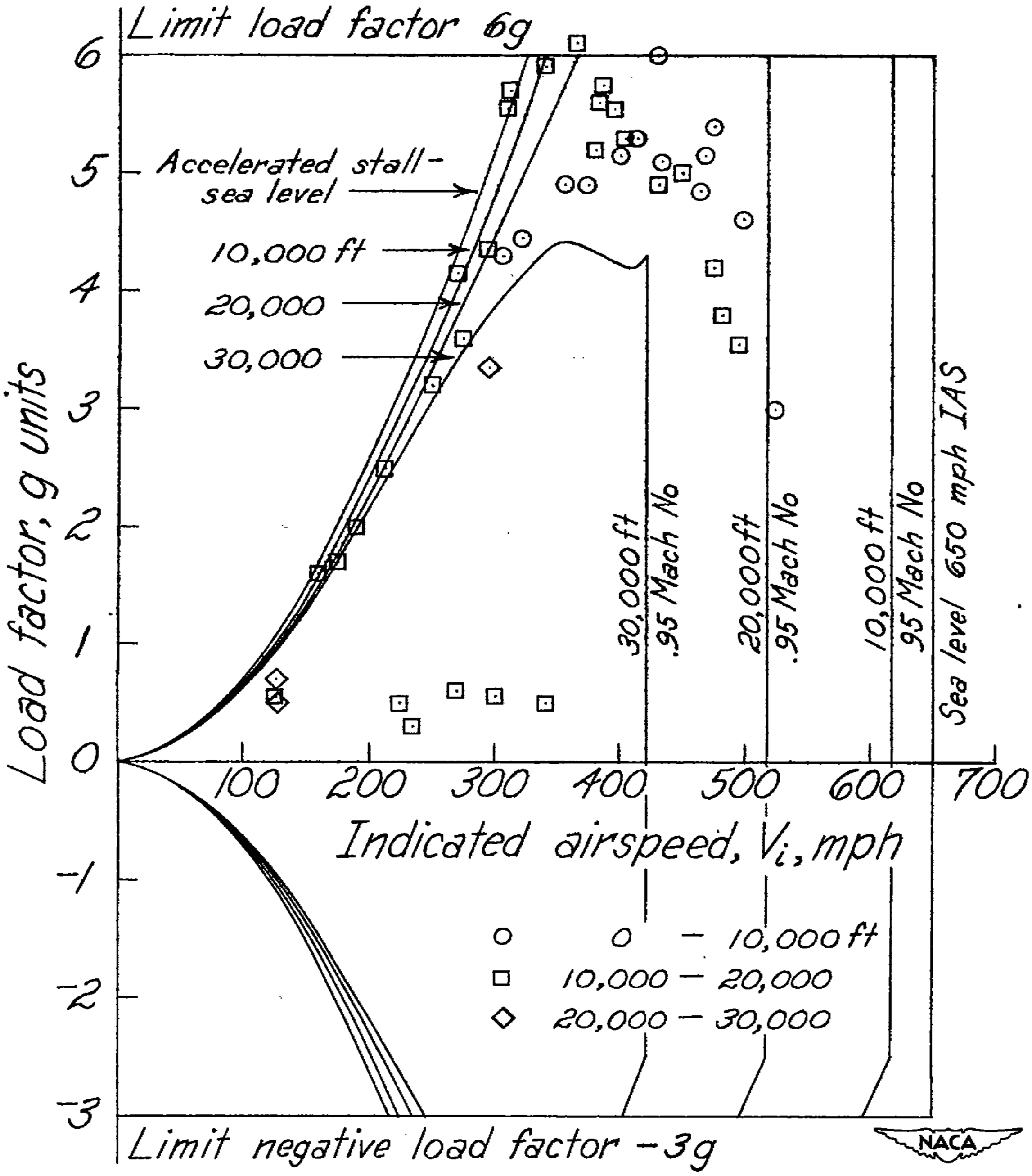

Figure 54.- Operational V-n diagram for F-86A airplane.

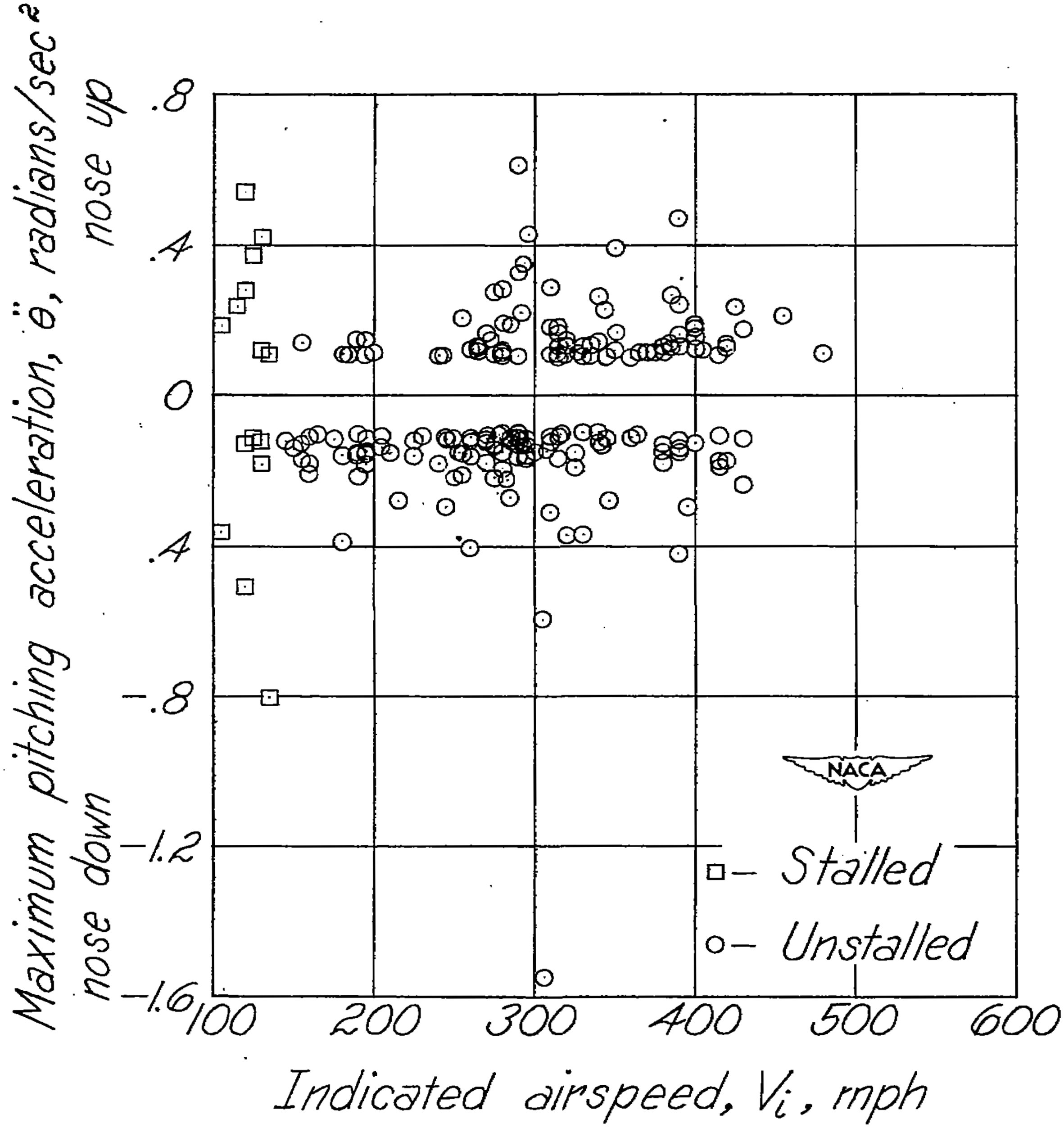

Figure 55.- Maximum pitching accelerations.

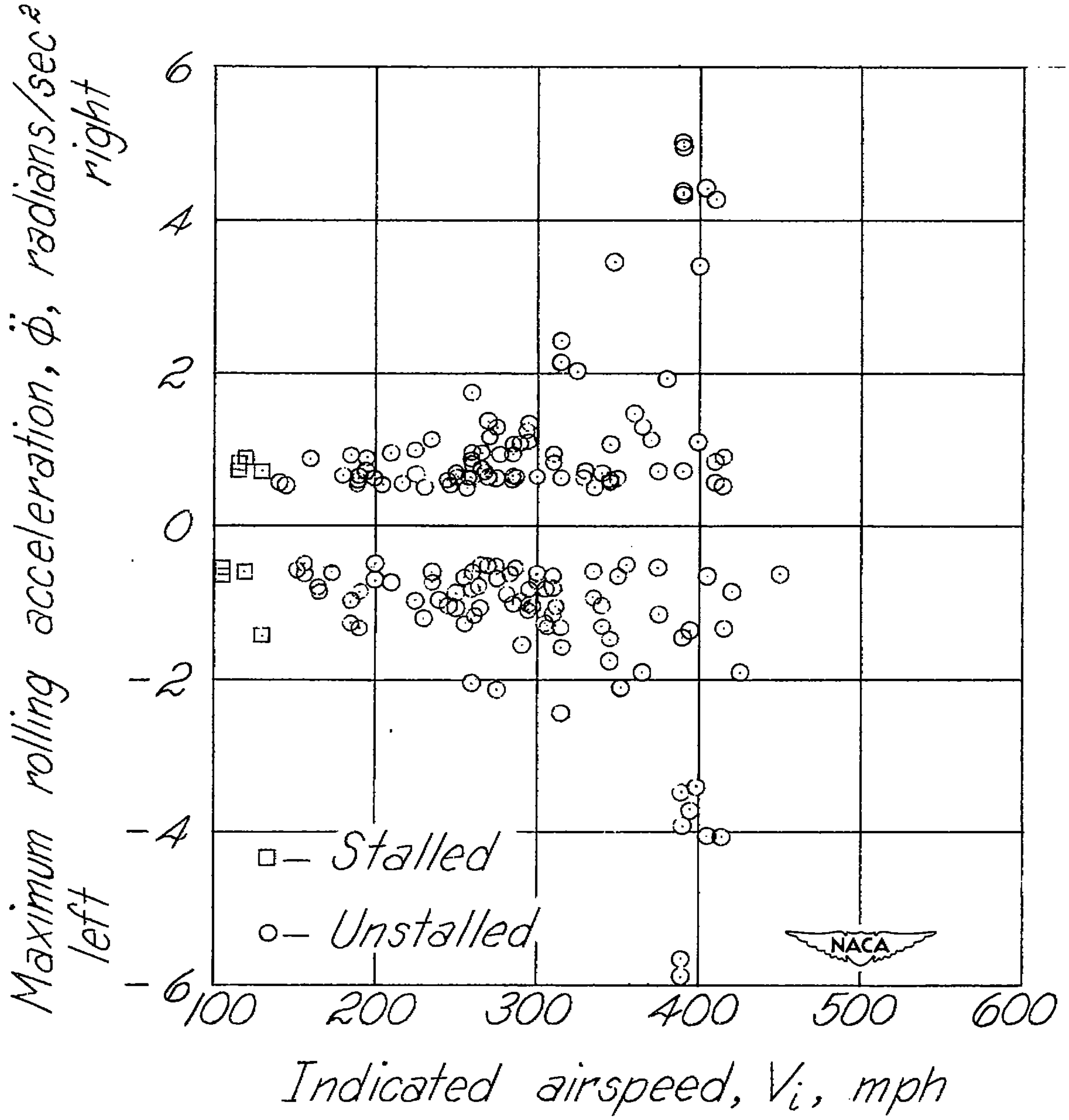

Figure 56.- Maximum rolling accelerations.

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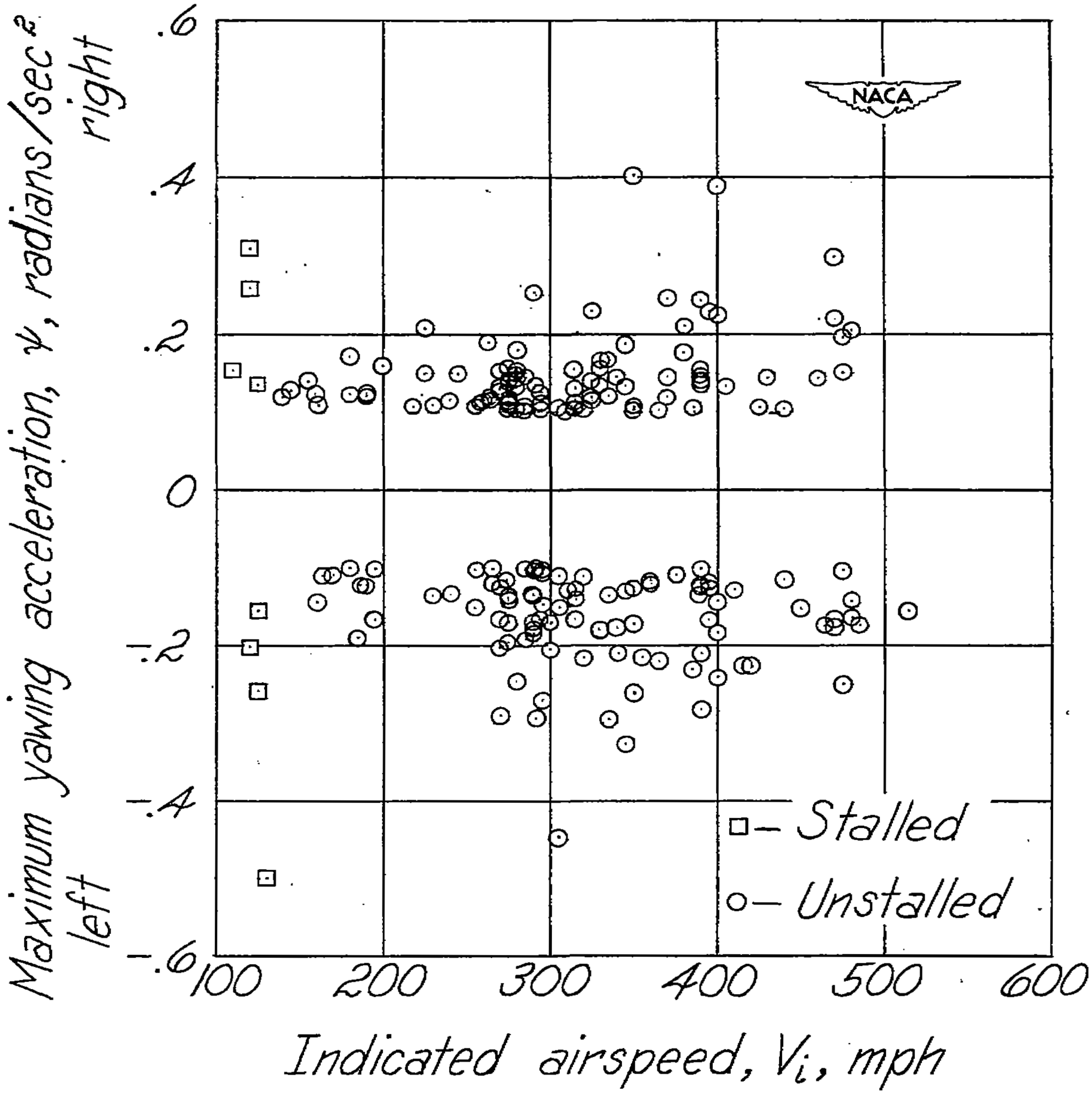

Figure 57.- Maximum yawing accelerations.

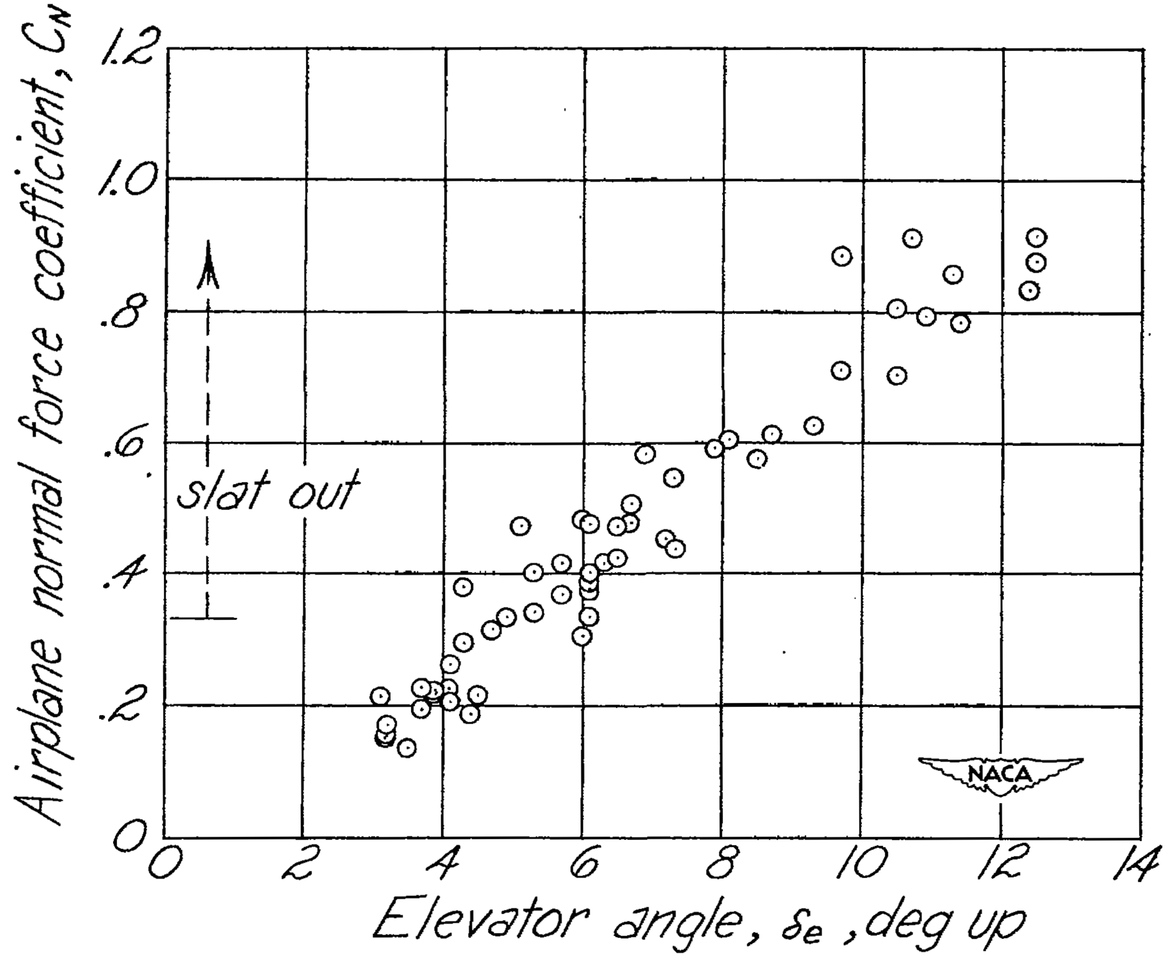

Figure 58.- Variation of elevator trim position with airplane normal-force coefficient for unaccelerated flight. Stabilizer angle, 0.3° (L.E. down); c.g., 23.0 to 23.6; weight, 13,400 to 11,750 pounds; M, 0.25 to 0.69.

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